ASIAC

REPORT NO. 180.1A

# DEVELOPMENT
# OF A
# BIAXIAL TEST FIXTURE



January 1980

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**AEROSPACE STRUCTURES**
**INFORMATION AND ANALYSIS CENTER**

**OPERATED FOR THE AIRFORCE FLIGHT DYNAMICS LABORATORY**
**BY ANAMET LABORATORIES, INC.**

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# OF A
# BIAXIAL TEST FIXTURE

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This report describes the development, fabrication and testing of fixturing designed to determine the biaxial properties of materials. The fixturing was designed to be particularly compatible with composite materials, although it is not limited to use with those materials. As part of the work, a second fixture was built which applies only internal pressure to thin ring specimens.

The work was done by the Aerospace Structures Information and Analysis Center, which is operated for the Air Force Flight Dynamics Laboratory, by Anamet Laboratories, Inc., under Contract No. F33615-77-C-3046. The work was performed under ASIAC Problem No. 112.

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# I. INTRODUCTION

The Aerospace Structures Information and Analysis Center has designed and fabricated a specimen load system for conducting biaxial material characterizations of composite materials. In particular, the system is useful for determining a major portion of the biaxial failure envelopes for composite materials. Portions of the triaxial failure surface where at least two of the principal stresses are negative may also be explored with the system. In addition, with proper control, the system may be used to evaluate the multiaxial fatigue properties of composites. Materials with high Poisson's ratios, which cannot usually be evaluated with ring burst tests, may be easily tested in the ASIAC system. Theoretical aspects of the system have been described in Anamet Laboratories, Inc. Report No. 277.502, "Technical Proposal for Test System for Conducting Biaxial Tests of Composite Laminates." Design of the test system is such that it is best used with any standard compression or universal testing machine with a minimum capacity of 100,000 lbs.

The test system, which is useful for examining quadrants II, III and IV of the biaxial stress plane, utilizes short cylindrical specimens. The specimens may be loaded with combinations of axial compression, internal pressure and external pressure. A unique feature of the test system is that end restraints are minimized by applying all loads through hydrostatic pressures. Hoop stresses are produced by applying internal or external pressures through the use of pressurized oil. Radial stresses may be produced by simultaneously applying internal and external pressures. Axial stress is induced through specimen interaction with a high pressure lubricant trapped between the specimen ends and parallel platens.

Because of the mechanism of loading, restraint to end dilation and twisting is governed by the viscous or plastic

shear strength of the lubricant. Lead foil, indium foil, polyethylene film and combination stacks of films and foils have been evaluated for use as the solid high pressure lubricant. The solid lubricant serves other functions in addition to minimizing restraint. For example, the foil compensates for slight irregularities and mismatch between platens and specimens. It also assists in the attainment of an oil-tight seal between the specimen ends and platens. Such a seal is necessary for the application of surface oil pressures.

This report describes the development of the system to date and some of the problems encountered. It also presents the results of biaxial testing of specially made and strain gaged composite specimens. The test results are quite encouraging, and they show that further refinement and use of the system is warranted.

## II. DESCRIPTION OF TEST SYSTEM

Principal components of the platen and pressure system are shown in Figure 1. A dimensioned drawing of the system is given in Figure 2. The small hollow cylinder acts as the lower platen. A step in the solid cylinder serves as the upper platen bearing surface. The upper platen is stepped to reduce the area perpendicular to the specimen axis. This reduces the axial load required to overcome the axial resultant of the oil pressure and allows a smaller testing machine to be used. The platens are made from through-hardened 4340 steel to minimize specimen damage to the platen surfaces. If damage or wear should occur, the through-hardening allows the platens to be reground without the necessity for repeating case hardening or heat treating.

Specimens compatible with the biaxial fixture are approximately 4 inch in diameter and less than 3 inches in length. Typical test specimens and foil gaskets are shown in Figure 3. The specimens are sandwiched between gaskets which bear against the two platens. Gasket performance was evaluated by crushing a series of Fiberglas epoxy specimens using various gasket combinations. During those tests, specimen hourglassing, or barreling, was monitored using dial gages. It was found that a laminate gasket consisting of 0.003 inch polyethylene sandwiched between 0.002 inch soft lead foil generally produced the least amount of hourglassing or barreling.

A photograph of the fixturing installed in an MTS Model 810, 110 kip, servohydraulic testing machine is given in Figure 4. In this figure, the specimen is about to be tested under axial compression. A self-aligning platen is secured to the load cell to eliminate eccentricity of the load axis. When internal pressure is applied, a splash guard and catch pan are incorporated in the system. For the application of external oil pressures, the heavy pressure collet is placed about the specimen,

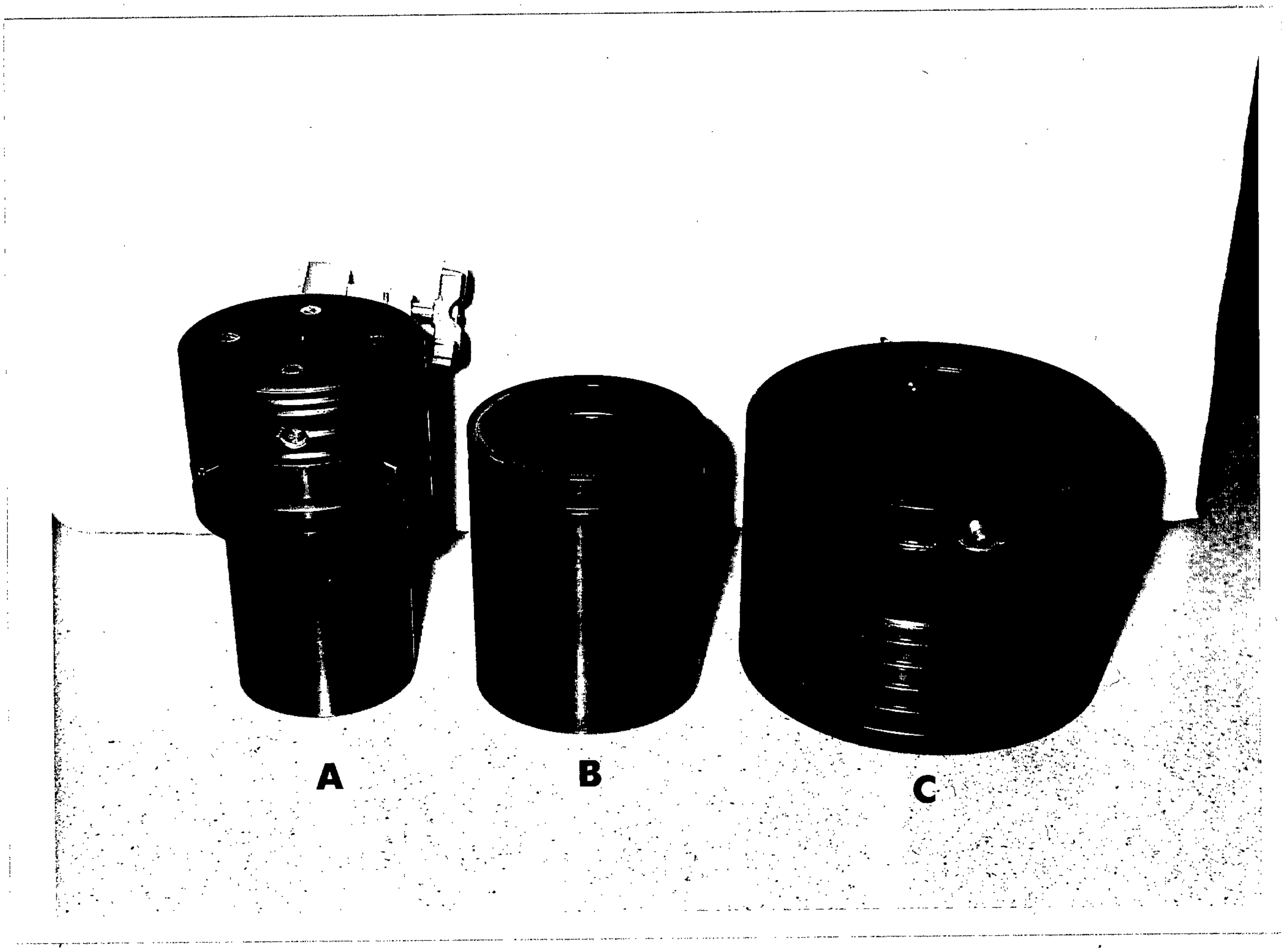


Figure 1 Principal Components of the Platen and Pressure System

A - Upper Platen
B - Lower Platen
C - External Pressure Collet

TEST FIXTURE

ANAMET LABS

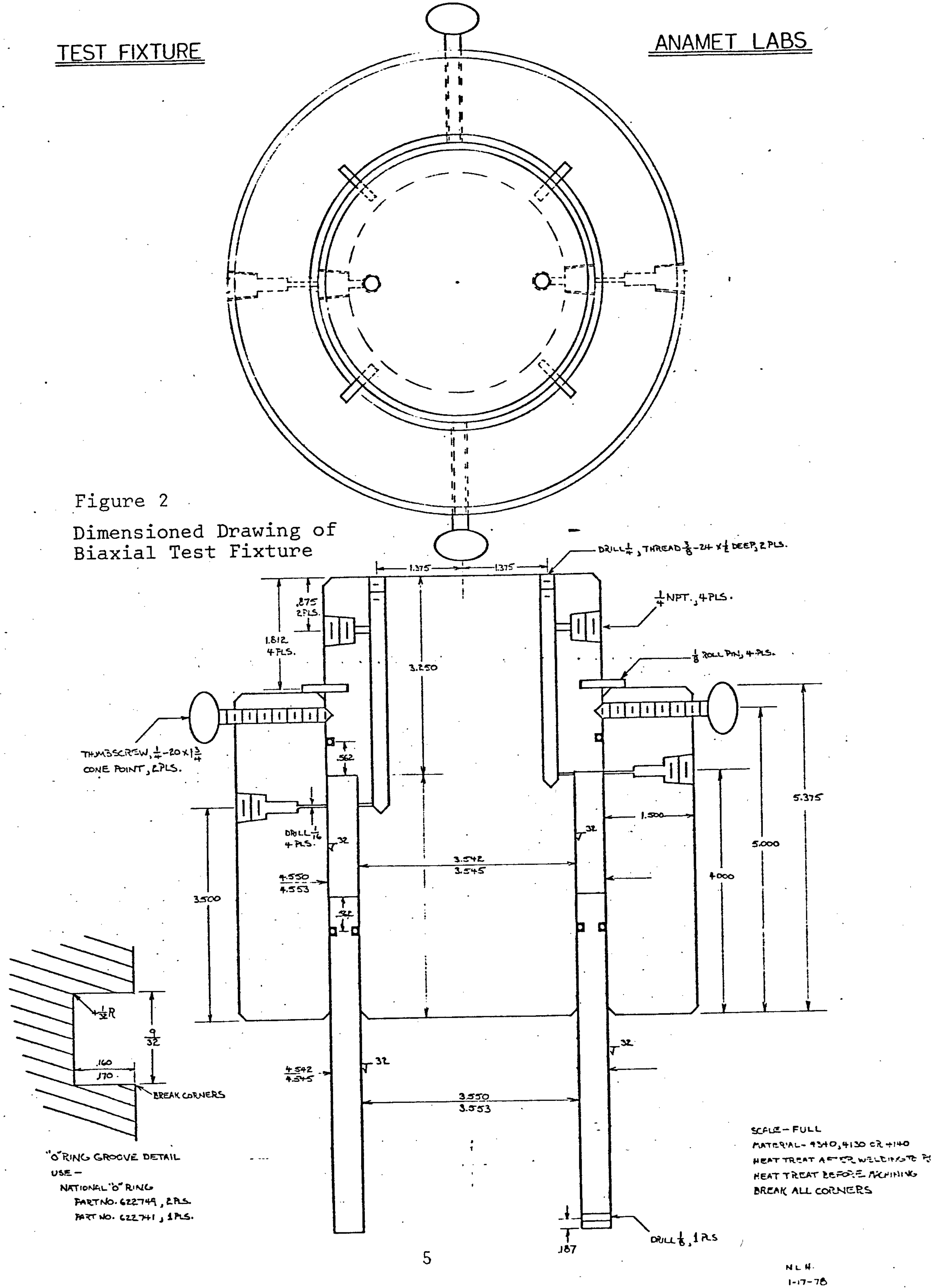


Figure 2

Dimensioned Drawing of Biaxial Test Fixture

Figure 3 Typical Test Specimens and Foil Gaskets

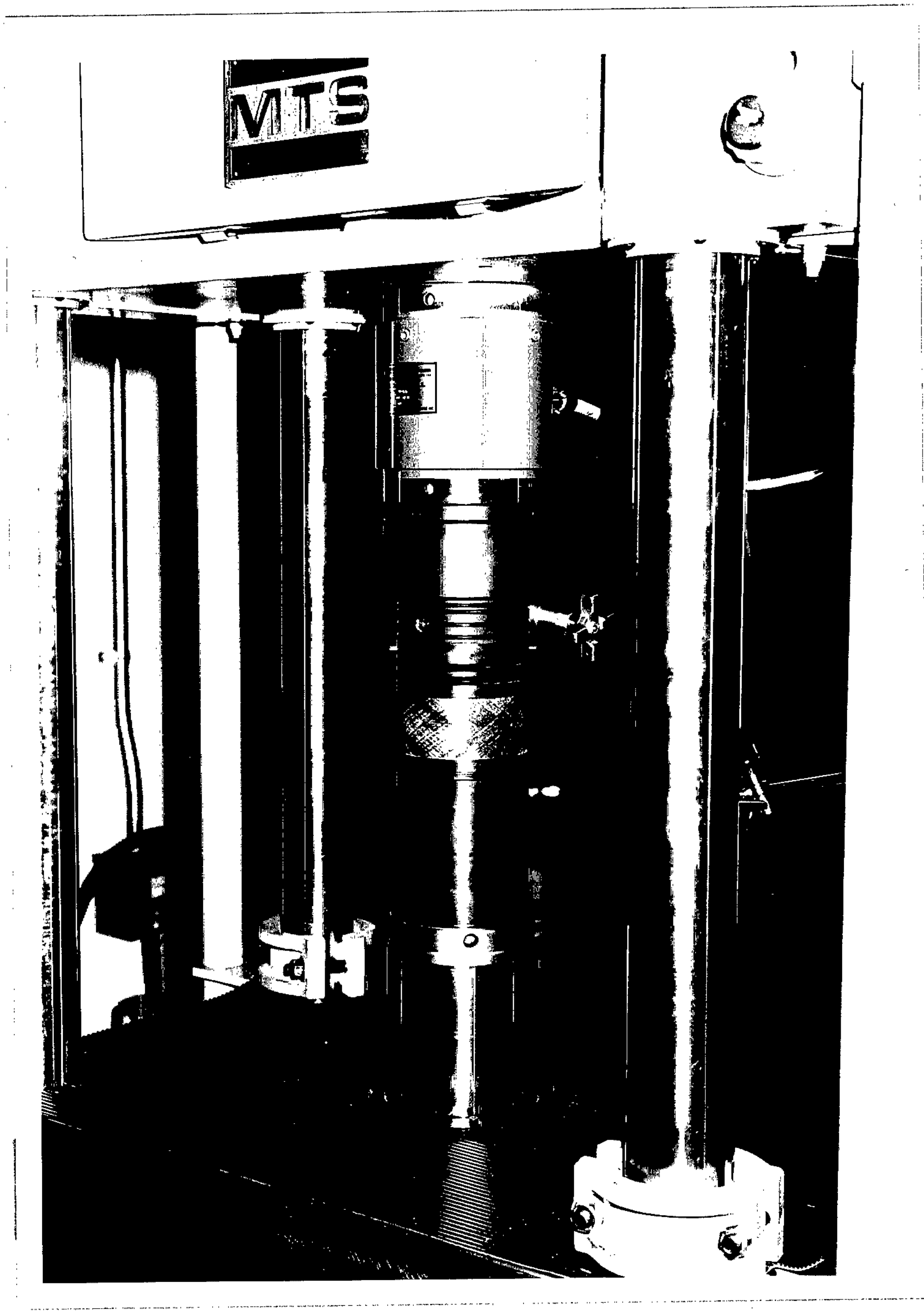


Figure 4 Fixture Installed in Testing Machine Prior to Axial Compression Test

as shown in Figure 5. The collet has been designed to withstand working pressures of 10,000 psi. In a few tests, an Enerpac 10,000 psi hydraulic power supply has been used to furnish the pressurized oil; however, hydraulic pressure for most of the tests was provided by an HIP, Inc. Model 87-6-5 manual pressure generator. Internal and external oil pressures were monitored with a standard pressure gage and a Datronic Model 502-3000G pressure transducer.

Many of the composite specimens tested in the fixture have been instrumented with resistive foil strain gages. Strain gage readings, as well as readings from the pressure transducer and MTS load cell, were taken using a Sun Systems ADACUS Data Processing and Readout System. This system contains an AD-I-SCE-10/32 Data Monitor with analog to digital converter, a DCP-10/P2/ADC-1 Display/Control Printer and two IM32/16 input multiplexers. Bridge completion, balancing and calibration are all internal to the Sun System. Internal calibrations are always checked with external shunt resistors. In the print mode, the ADACUS System scans at a rate of $2\frac{1}{2}$ channels per second. As composite materials may be viscoelastic, the strain gage data should be taken as rapidly as possible. To speed up the system scan rate, the ADACUS System was modified to bypass the printer and send the data directly to the memory of an IMSAI 8080 microprocessor. This allowed the scan rate to be increased to $12\frac{1}{2}$ channels per second. After completion of a test, the stored data was read into an ASR33 TTY, where punch tape and hardcopy records were made. Later, the punch tapes were read through the ASR33 and a file created in a PDP11/34. Loads corresponding to strain values were found through linear interpolation with time. A specially written program in the PDP11/34 allowed plots to be made of strains vs. stresses (see Appendix A). The plots were made on a TEKTRONIX Model 4631 hardcopy unit.

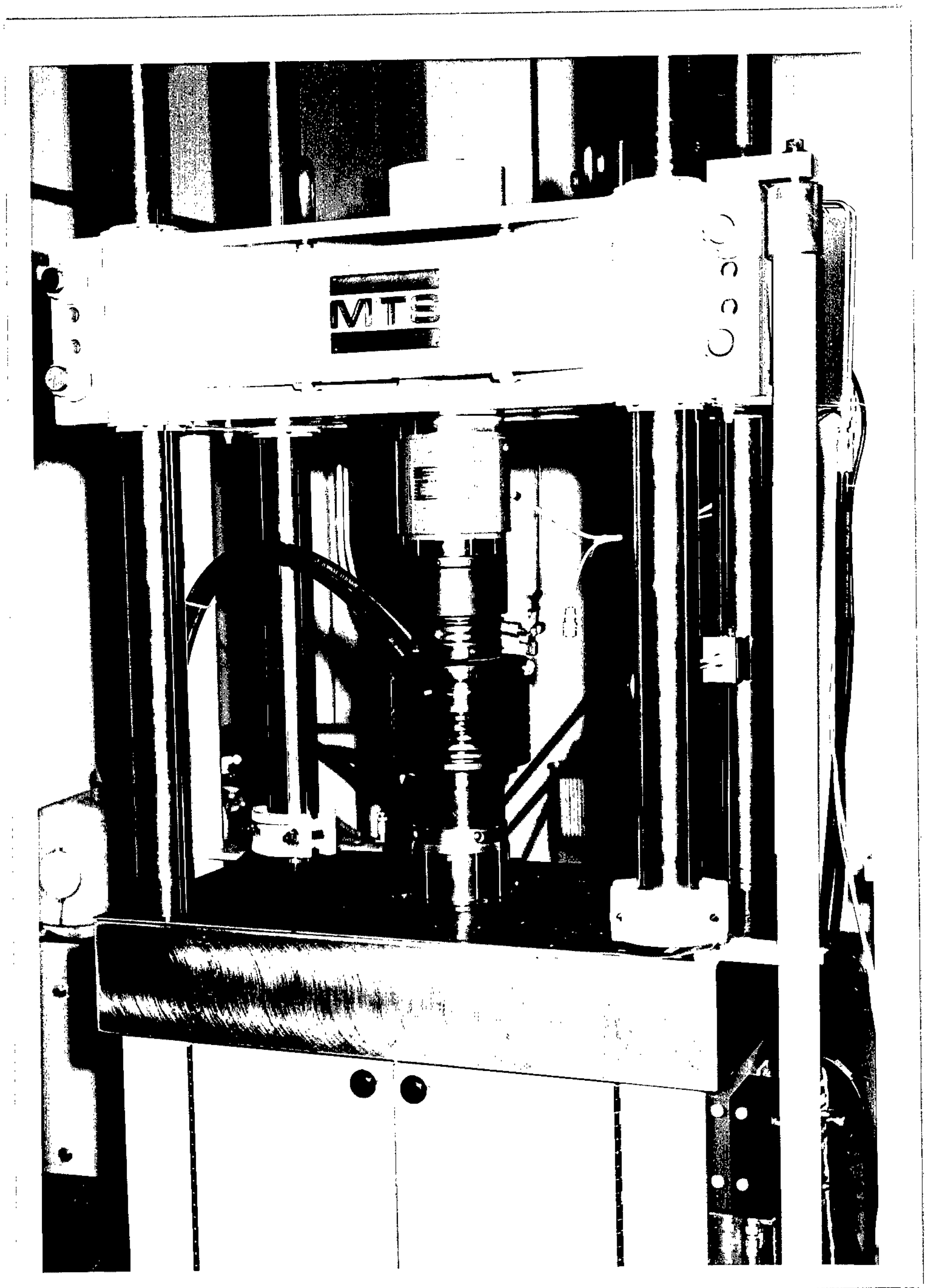


Figure 5 Fixture Installed in Testing Machine Prior to External Pressure and Axial Compression Test

It was discovered early in the program that the foil gaskets by themselves could not adequately contain the pressurized oil. To overcome this problem, and to prevent the oil from contacting the specimens, rubber gaskets were designed and incorporated into the system. The gaskets were molded from butyl rubber with a Shore A hardness of 60. They were precision molded tubes with wall thicknesses of 0.125 inches and heights 0.025 inches higher than the composite specimens. The rubber gasket diameters were such that some gaskets could be slipped inside the specimens and others could be slipped outside the specimens. Small openings were cut in the rubber gaskets to allow penetration of strain gage leads. After the leads were passed through the openings, RTV rubber was applied as a sealant. Small connector plugs were epoxy potted inside the pressure collet and in a groove machined in the center plug. Strain gage leads were terminated with plugs mating with the potted plugs. With this arrangement, hydraulic oil pressures could be applied to the specimens, and at the same time, strain gage readings taken.

## III. DESCRIPTION OF SPECIMENS

In the initial development of the system, numerous specimens were tested to evaluate various gasket combinations and seal systems. Those tests were largely qualitative, and data was not recorded. Due to availability and attractive cost, the preliminary test specimens were made from Bondstrand 2000 Fiberglas-reinforced epoxy resin pipe. Details of the ply layup were unknown; however, it appeared to be a wound ±45° structure. The Fiberglas epoxy specimens had an outside diameter of 4.375 in., a wall thickness of typically 0.100 in. and heights of either 1.000 in. or 2.000 in.

After seal and gasket problems were solved, a number of uninstrumented graphite-epoxy specimens were tested under internal pressure and axial load. Those specimens had outside diameters of 4.000 in., wall thicknesses of 0.043 in. and heights of either 1.000 in. or 2.000 in. Localized buckling problems with the first two of these specimens suggested the specimen ends were either not flat or not parallel. Careful measurements of the remaining specimens disclosed variations in height of as much as ±0.003 inches. The specimen ends were then ground flat and parallel to within 0.0005 in. With this change, the localized buckling problems ceased. The purpose of the preliminary graphite-epoxy tests was to use dial gages to semi-quantitatively evaluate system performance with relatively thin walled high strength materials.

As the preliminary graphite-epoxy tests yielded promising results, a series of tests were performed on carefully made strain gaged specimens. The specimens were graphite-epoxy, and measured 4.000 inches O.D., were 1.000 inches high and had a wall thickness of 0.043 inches. The ends were ground flat and parallel to within 0.0005 inches. Four specimens had a $[0°/\pm45°/90°]_S$ ply layup. All specimens were strain gaged, as shown in Figure 6. The instrumented specimens were provided by AFFDL.

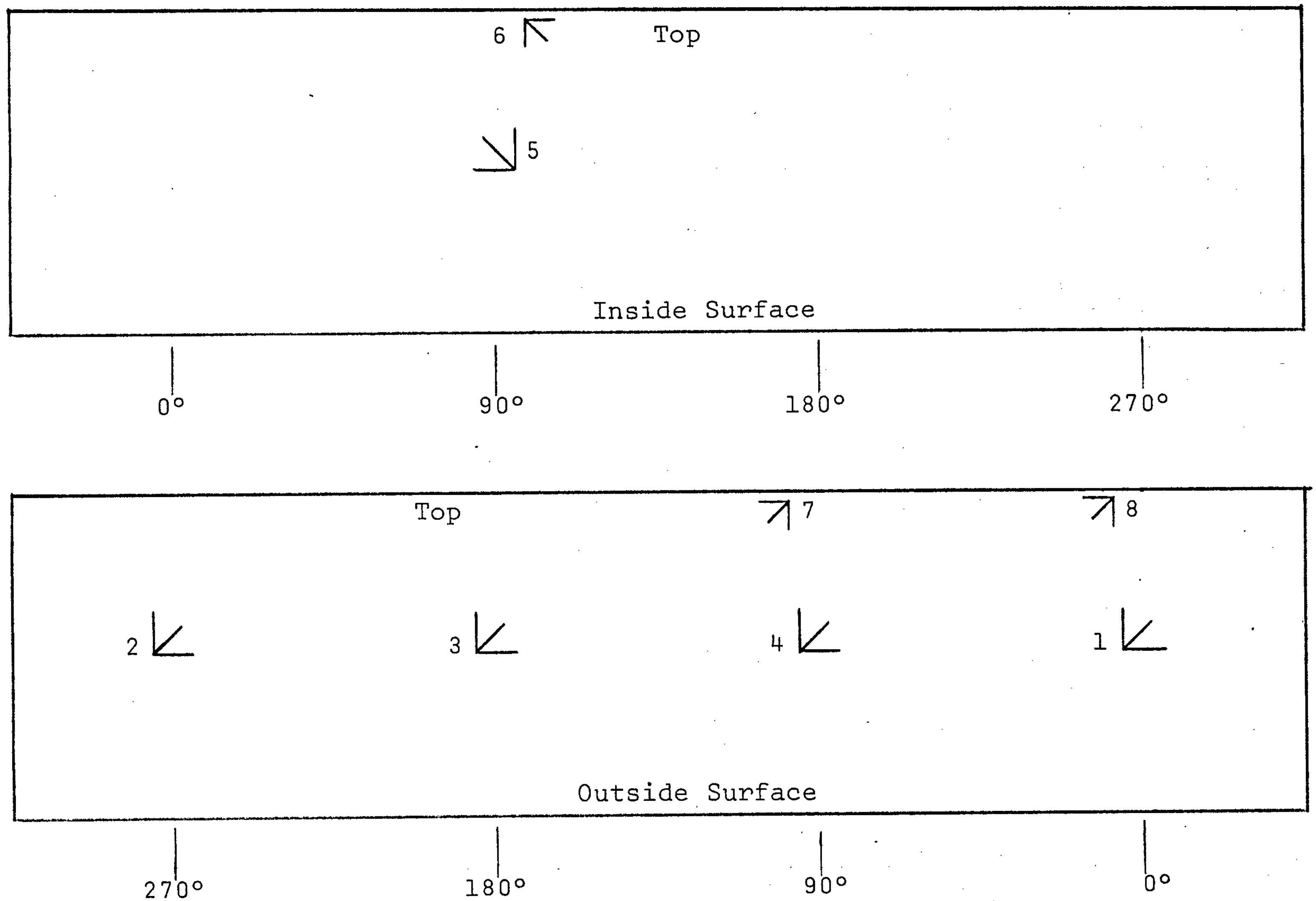


Figure 6 Unrolled view of specimen showing relative rosette locations and identifications. Rosettes 6, 7 & 8 are stacked rosettes with 0.062" gage lengths. The remaining rosettes are standard rosettes with 0.125" gage lengths.

## IV. TEST RESULTS

Tests performed on the seven strain gaged specimens are summarized in Table 1.

TABLE 1

SUMMARY OF TESTS

| Test No. | Specimen Type | Loading | Notes |
|---|---|---|---|
| 1 | ±45° | Axial only | |
| 2 | 0°/±45°/90° | Internal pressure | 200 lb. axial preload |
| 3 | ±45° | Internal pressure | Constant 100 lb. axial load |
| 4-A | ±45° | Axial only | Same specimen, partial compressions |
| 4-B | ±45° | Axial only | Same specimen, partial compressions |
| 4-C | ±45° | Axial only | Same specimen, partial compressions |
| 5 | ±45° | External pressure | Same specimen as used in 4-A,B,C |
| 6 | 0°/±45°/90° | Internal pressure and axial load | Internal pressure equals axial load, pure shear condition |
| 7 | 0°/±45°/90° | External pressure and axial load | Hoop stress equal to axial stress |
| 8 | 0°/±45°/90° | External pressure | Edge damaged - not tested |

For each of the tests performed, stress-strain plots were created from strain gage, load cell and pressure transducer outputs. The stress-strain plots for each test are summarized in Table 2.

TABLE 2

SUMMARY OF PLOTS

| Test No. | Description | Rosette Nos. | Figure No. |
|---|---|---|---|
| 1 | Axial strain vs. axial stress | 1,2,3,4 | 7 |
| | Axial strain vs. axial stress | 4,5 | 8 |
| | Axial strain vs. axial stress | 7,8 | 9 |
| | Hoop strain vs. axial stress | 2,3,4 | 11 |
| | Hoop strain vs. axial stress | 4,5 | 12 |
| | Hoop strain vs. axial stress | 6,7,8 | 13 |
| | Max. shear strain vs. axial stress | 2,3,4 | 14 |
| | Max. shear strain vs. axial stress | 4,5 | 15 |
| | Max. shear strain vs. axial stress | 6,7,8 | 16 |
| 2 | Axial strain vs. hoop stress | 1,2,3,4 | 17 |
| | Axial strain vs. hoop stress | 4,5 | 20 |
| | Axial strain vs. hoop stress | 6,7,8 | 23 |
| | Hoop strain vs. hoop stress | 1,2,3,4 | 18 |
| | Hoop strain vs. hoop stress | 4,5 | 21 |
| | Hoop strain vs. hoop stress | 6,7,8 | 24 |
| | Max. shear strain vs. hoop stress | 1,2,3,4 | 19 |
| | Max. shear strain vs. hoop stress | 4,5 | 22 |
| | Max. shear strain vs. hoop stress | 7,8 | 25 |
| 3 | Axial strain vs. hoop stress | 1,2,3,4 | 27 |
| | Axial strain vs. hoop stress | 4,5 | 30 |
| | Axial strain vs. hoop stress | 6,7,8 | 33 |
| | Hoop strain vs. axial stress | 1,2,3,4 | 28 |
| | Hoop strain vs. axial stress | 4,5 | 31 |
| | Hoop strain vs. axial stress | 6,7,8 | 34 |
| | Max. shear strain vs. hoop stress | 1,2,3,4 | 29 |
| | Max. shear strain vs. hoop stress | 4,5 | 32 |
| | Max. shear strain vs. hoop stress | 6,7,8 | 35 |
| 4-A | Axial strain vs. axial stress | 1,2,3,4 | 37 |
| | Axial strain vs. axial stress | 4,5 | 40 |
| | Axial strain vs. axial stress | 6,7,8 | 43 |
| | Hoop strain vs. axial stress | 1,2,3,4 | 38 |
| | Hoop strain vs. axial stress | 4,5 | 41 |
| | Hoop strain vs. axial stress | 6,7,8 | 44 |
| | Max. shear strain vs. axial stress | 1,2,3,4 | 39 |
| | Max. shear strain vs. axial stress | 4,5 | 42 |
| | Max. shear strain vs. axial stress | 6,7,8 | 45 |

TABLE 2
(Continued)

| Test No. | Description | Rosette Nos. | Figure No. |
|---|---|---|---|
| 4-B | Axial strain vs. axial stress | 1,2,3,4 | 46 |
| | Axial strain vs. axial stress | 4,5 | 49 |
| | Axial strain vs. axial stress | 6,7,8 | 52 |
| | Hoop strain vs. axial stress | 1,4 | 47 |
| | Hoop strain vs. axial stress | 4,5 | 50 |
| | Hoop strain vs. axial stress | 6,7,8 | 53 |
| | Max. shear strain vs. axial stress | 1,4 | 48 |
| | Max. shear strain vs. axial stress | 4,5 | 51 |
| | Max. shear strain vs. axial stress | 6,7,8 | 54 |
| 4-C | Axial strain vs. axial stress | 1,2,3,4 | 55 |
| | Axial strain vs. axial stress | 4,5 | 58 |
| | Axial strain vs. axial stress | 6,7,8 | 61 |
| | Hoop strain vs. axial stress | 1,2,3,4 | 56 |
| | Hoop strain vs. axial stress | 4,5 | 59 |
| | Hoop strain vs. axial stress | 6,7,8 | 62 |
| | Max. shear strain vs. axial stress | 1,2,3,4 | 57 |
| | Max. shear strain vs. axial stress | 4,5 | 60 |
| | Max. shear strain vs. axial stress | 6,7,8 | 63 |
| 5 | Axial strain vs. hoop stress | 5,6 | 68 |
| | Hoop strain vs. hoop stress | 5,6 | 69 |
| | Max. shear strain vs. hoop stress | 5,6 | 70 |
| 6 | Axial strain vs. axial stress | 1,2,3 | 73 |
| | Axial strain vs. axial stress | 6,7,8 | 74 |
| | Hoop strain vs. hoop stress | 1,2,3,4 | 75 |
| | Hoop strain vs. hoop stress | 4,5 | 76 |
| | Hoop strain vs. hoop stress | 7,8 | 77 |
| 7 | Axial strain vs. axial stress | 1,2,4 | 80 |
| | Axial strain vs. axial stress | 4,5 | 82 |
| | Axial strain vs. axial stress | 7,8 | 83 |
| | Hoop strain vs. hoop stress | 1,2,3,4 | 85 |
| | Hoop strain vs. hoop stress | 7,8 | 86 |
| | Max. shear strain vs. axial stress | 1,2 | 81 |
| | Max. shear strain vs. axial stress | 7,8 | 84 |

Only axial load was applied to the specimen in Test 1. The specimen layup was ±45°. Figure 7 is a comparison of the axial strains vs. axial stress for the four gages located at the center of the specimen on the outside surface. The axial strain gage elements were not in close agreement, indicating either non-uniformity of load or local variations in specimen compliance. The specimen began to buckle when a compressive axial stress of approximately 19,000 psi was reached. This is shown by the curving back of the axial stress in this plot. Figure 8 is a comparison of the axial strains vs. axial stress for the two gages located at the center of the specimen but on opposite surfaces. The output from these gages show that no bending, and thus no buckling, was occurring at this position. Figure 9 is a comparison plot of axial strains vs. axial stress for the two gages located at the top of the specimen but on opposite surfaces. These figures show that the output from the gages at Points 1, 4, 5, 6, 7 and 8 compare fairly well, but do not compare with the output from gages at Points 2 and 3. Figure 10 is a photograph of this specimen after testing. This figure shows that the buckles occurred on the end opposite from gages at Points 6, 7 and 8. Figure 11 is a comparison plot of hoop strains vs. axial stress for three gages located at the center of the specimen on the outside surface. The hoop strain component for the strain rosette at Point 1 did not produce a signal. The shape of these curves matched the corresponding curves shown in Figure 7. Figures 12 and 13 are the comparison plots of hoop strains vs. axial stress for the gage locations corresponding to those of Figures 8 and 9, respectively. Again, the shapes of the curves are in agreement with the corresponding axial strain curves. Figures 14, 15 and 16 are comparison plots of the maximum shear strain vs. axial load for the gage locations presented in Figures 7, 8 and 9, respectively.

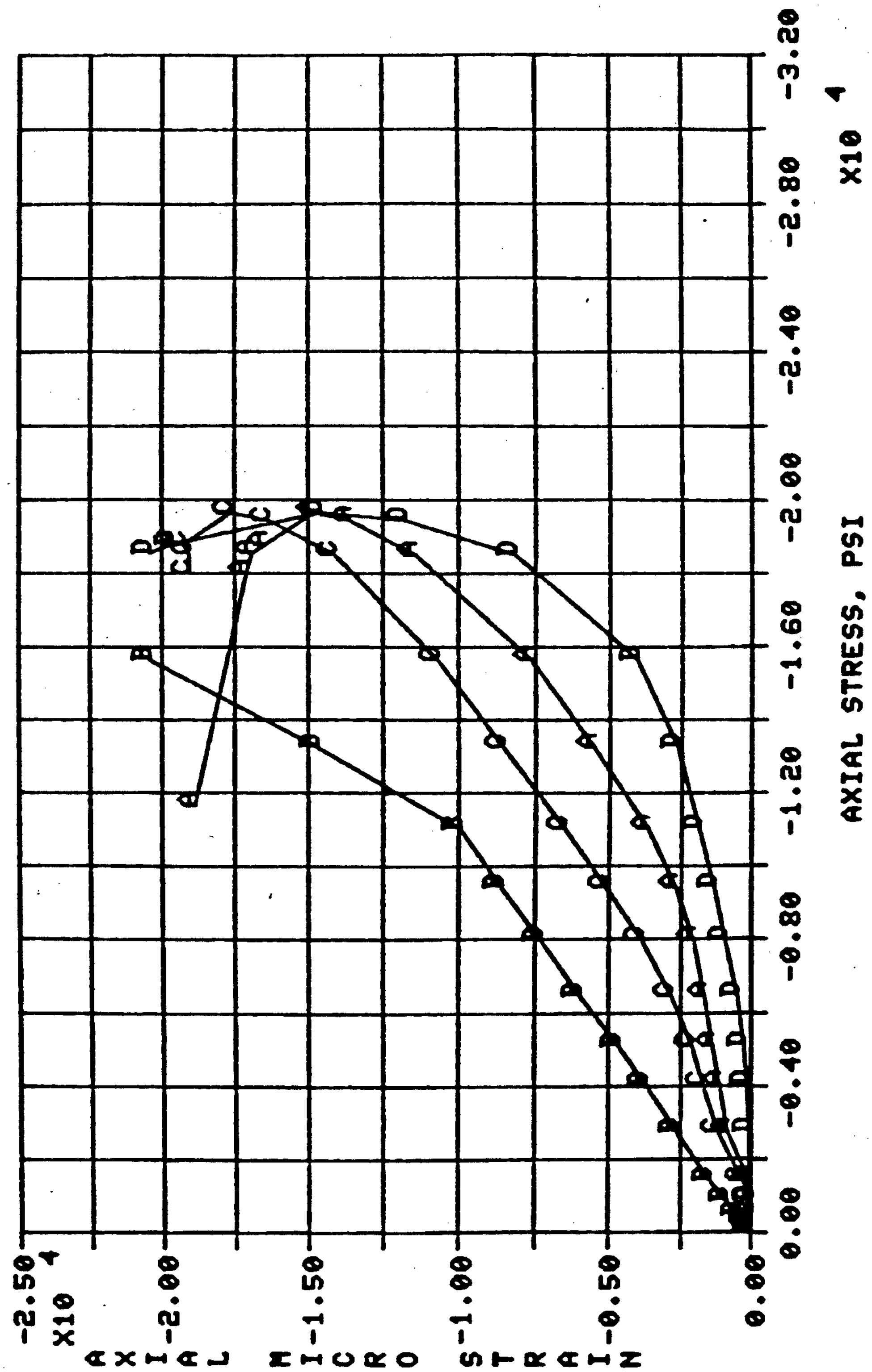


Figure 7 Test 1. Layup ±45° Axial Load Only
Axial Response, Outside Rosettes

A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4

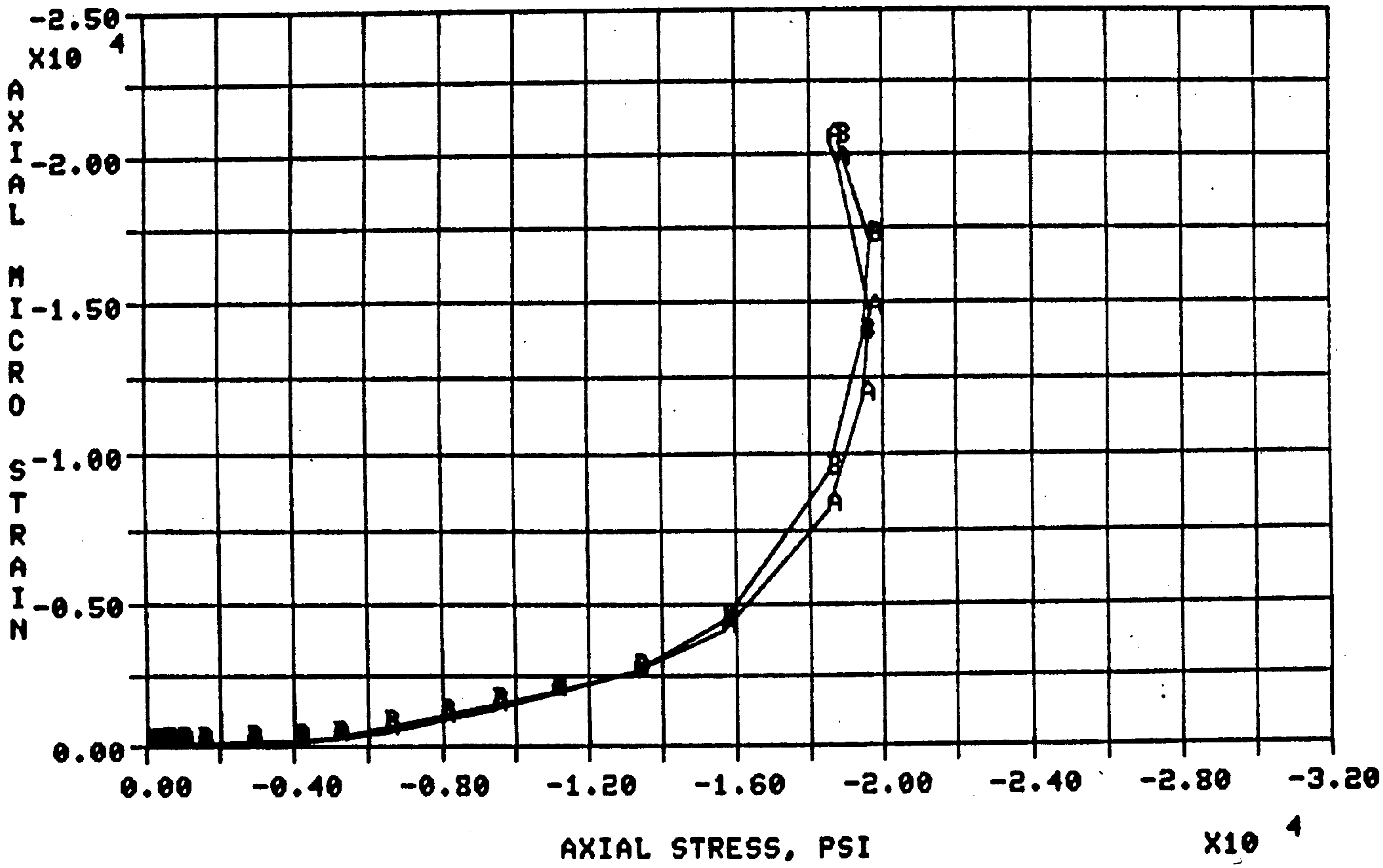


Figure 8 Test 1. Layup ±45° Axial Load Only
Axial Response, Inside/Outside Rosettes

A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)

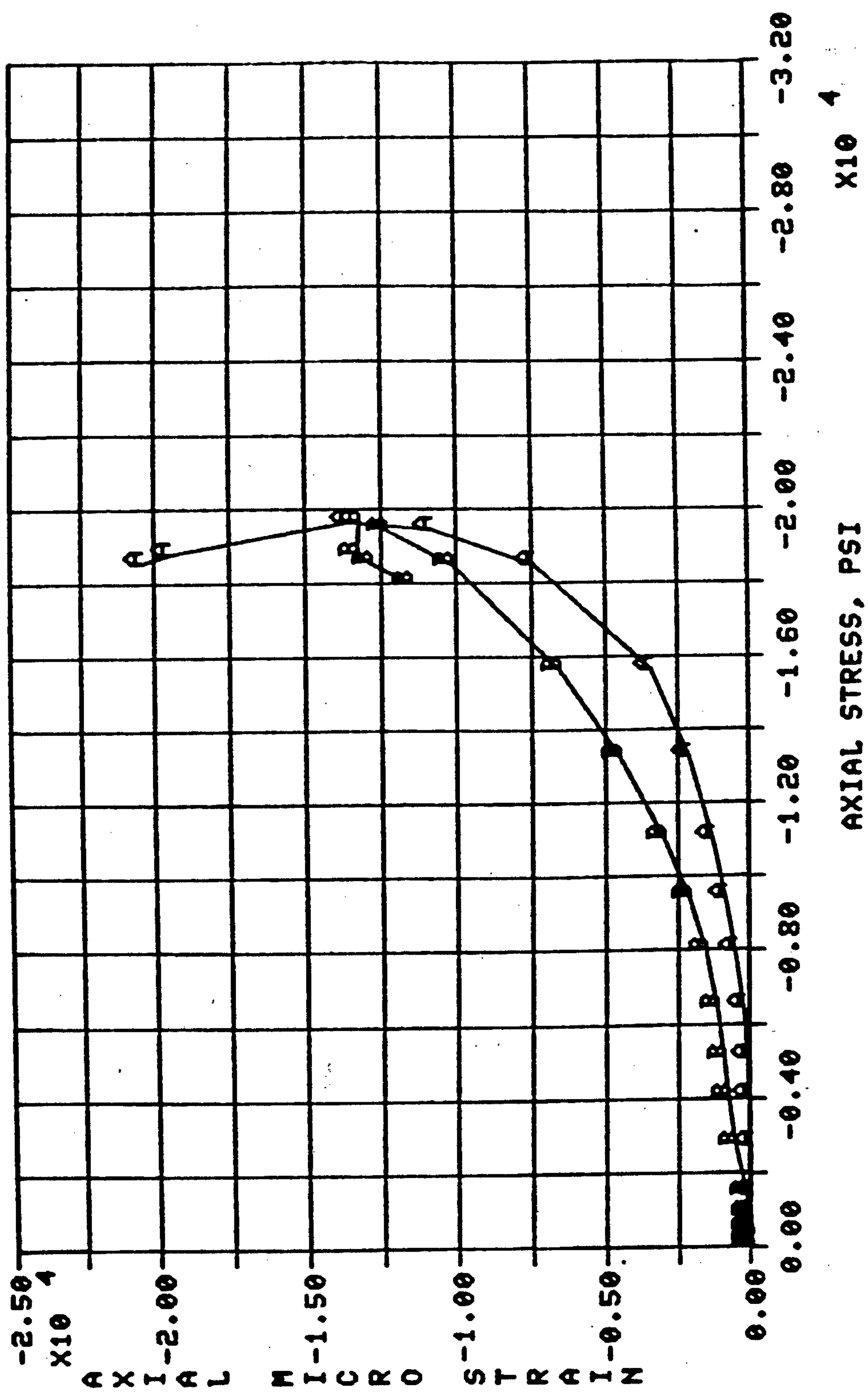


Figure 9 Test 1. Layup ±45° Axial Load Only
Axial Response, Edge Rosettes

A - Rosette No. 7
B - Rosette No. 8

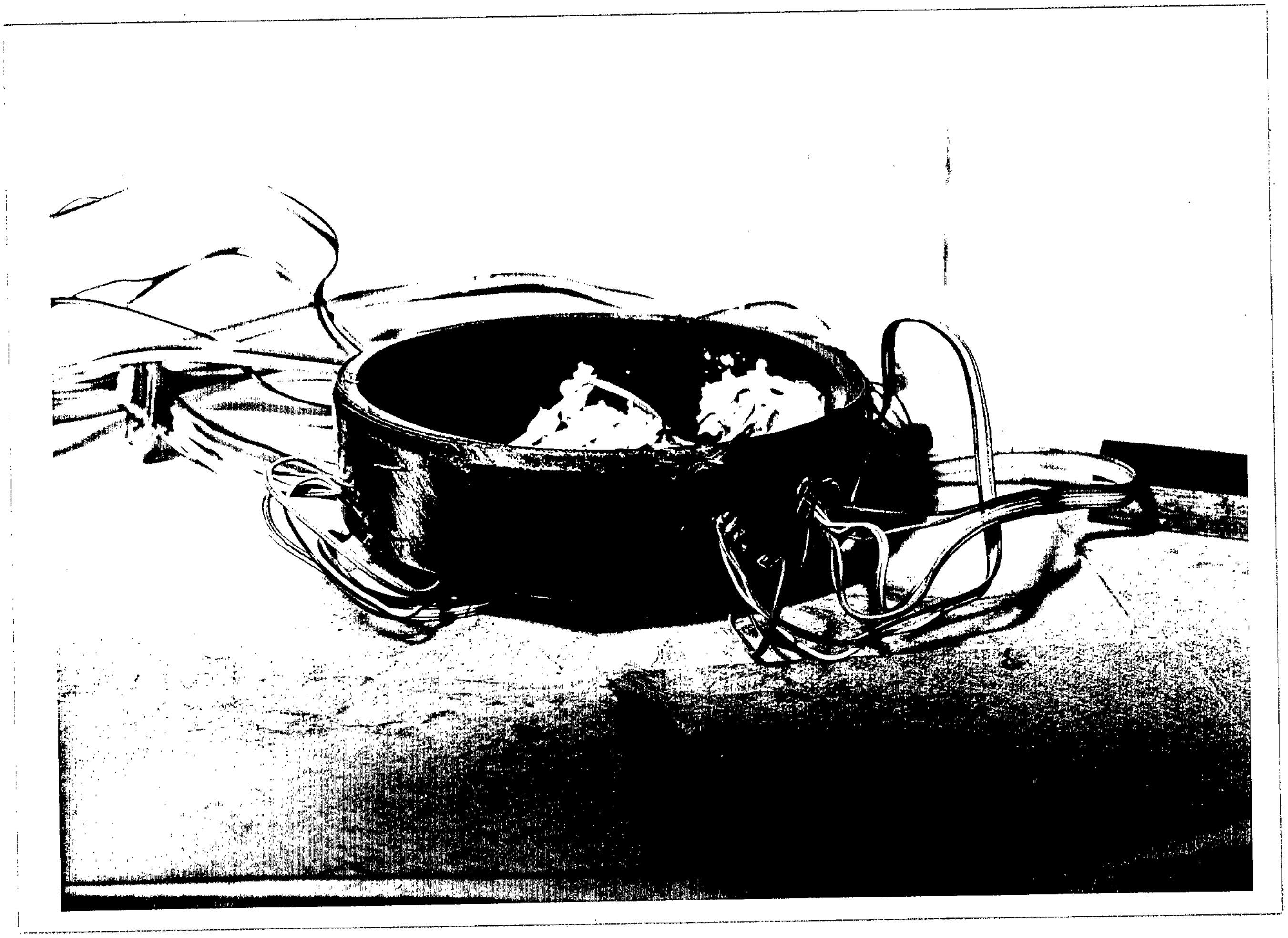

Figure 10 Test Specimen No. 1 After Crushing by Axial Load. Ply Layup is ±45°.

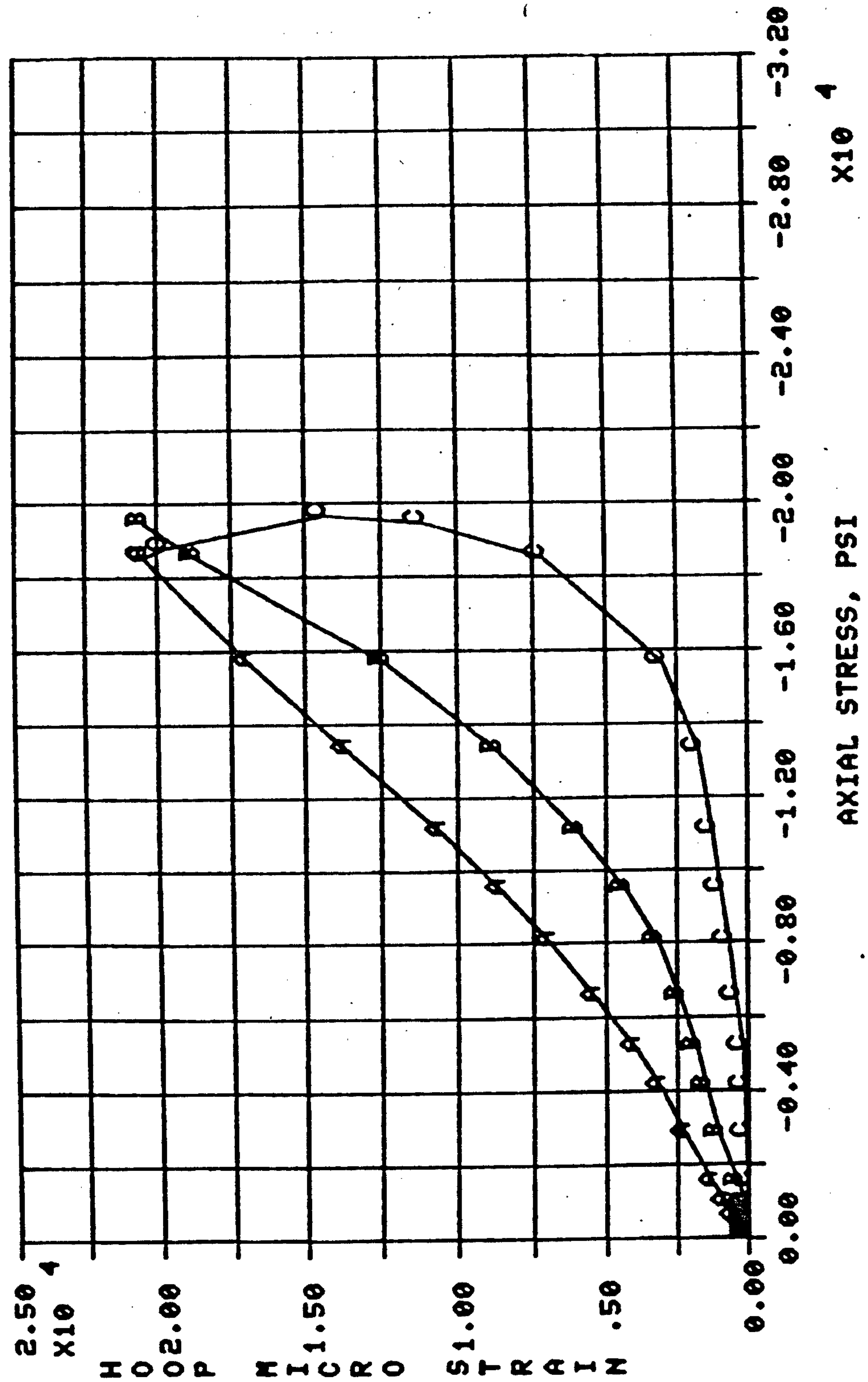


Figure 11 Test 1. Layup ±45°, Axial Load Only
Hoop Response, Outside Rosettes

A - Rosette No. 2
B - Rosette No. 3
C - Rosette No. 4

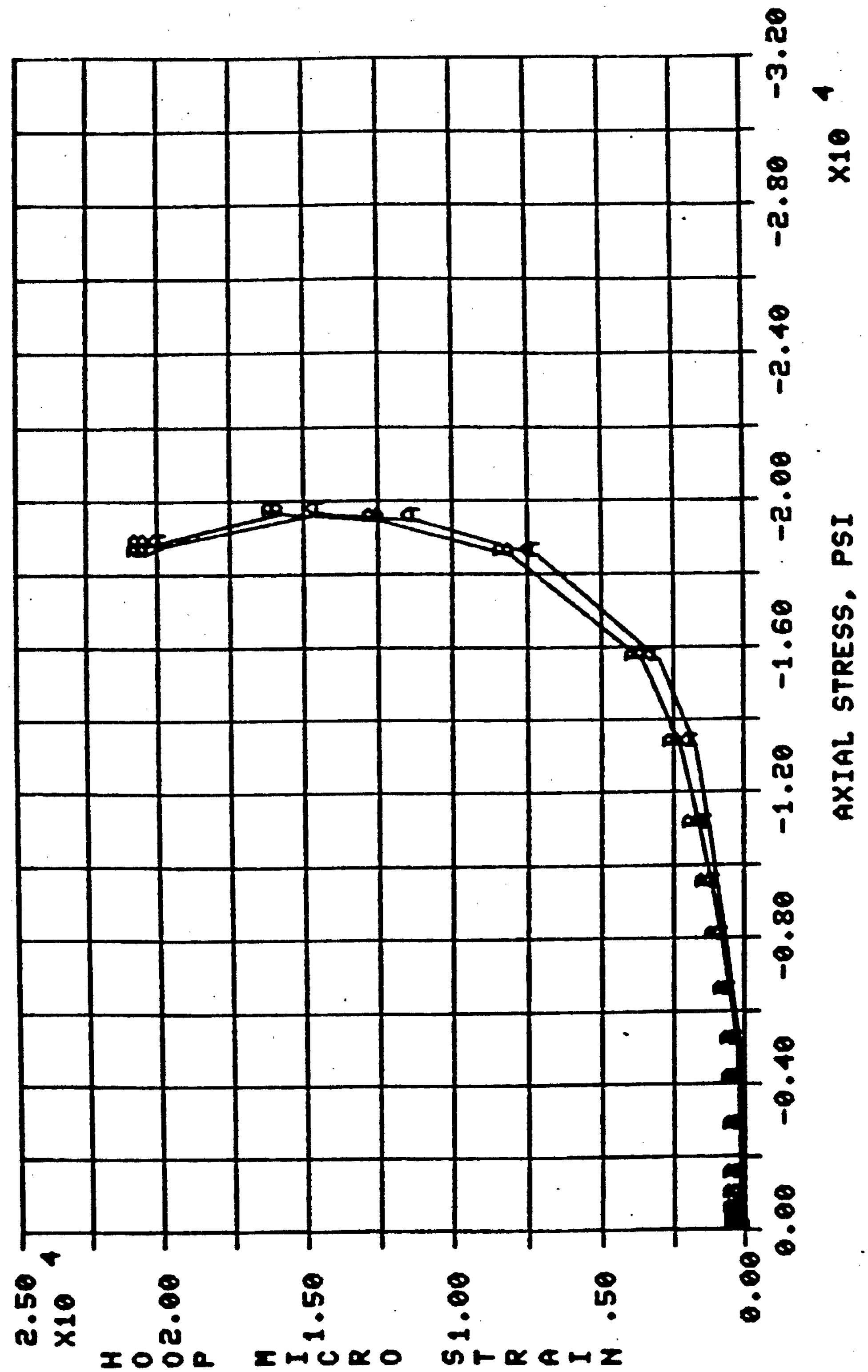


Figure 12 Test 1. Layup ±45° Axial Load Only
Hoop Response, Inside/Outside Rosettes

A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)

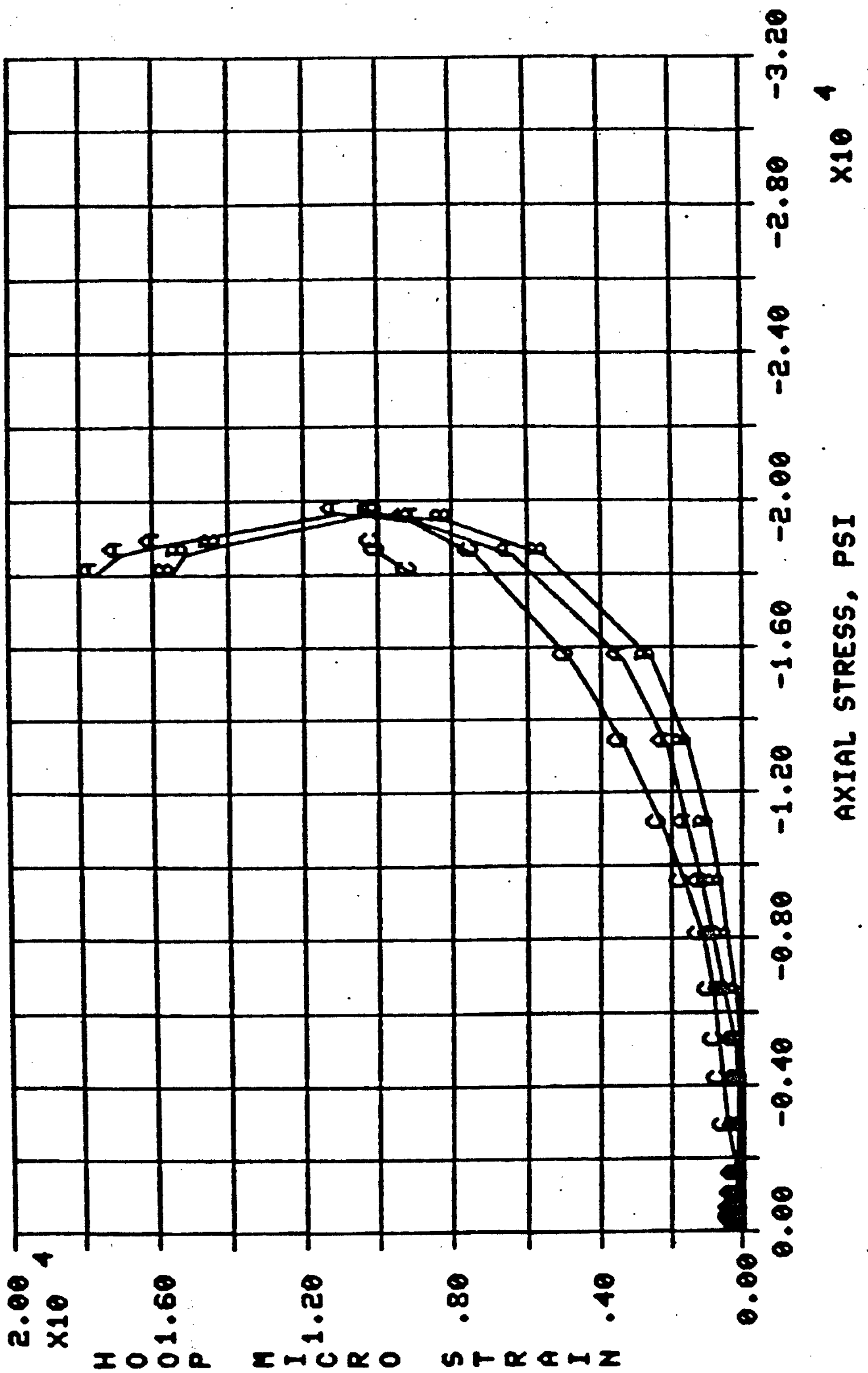


Figure 13 Test 1. Layup ±45° Axial Load Only
Hoop Response, Edge Rosettes

A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8

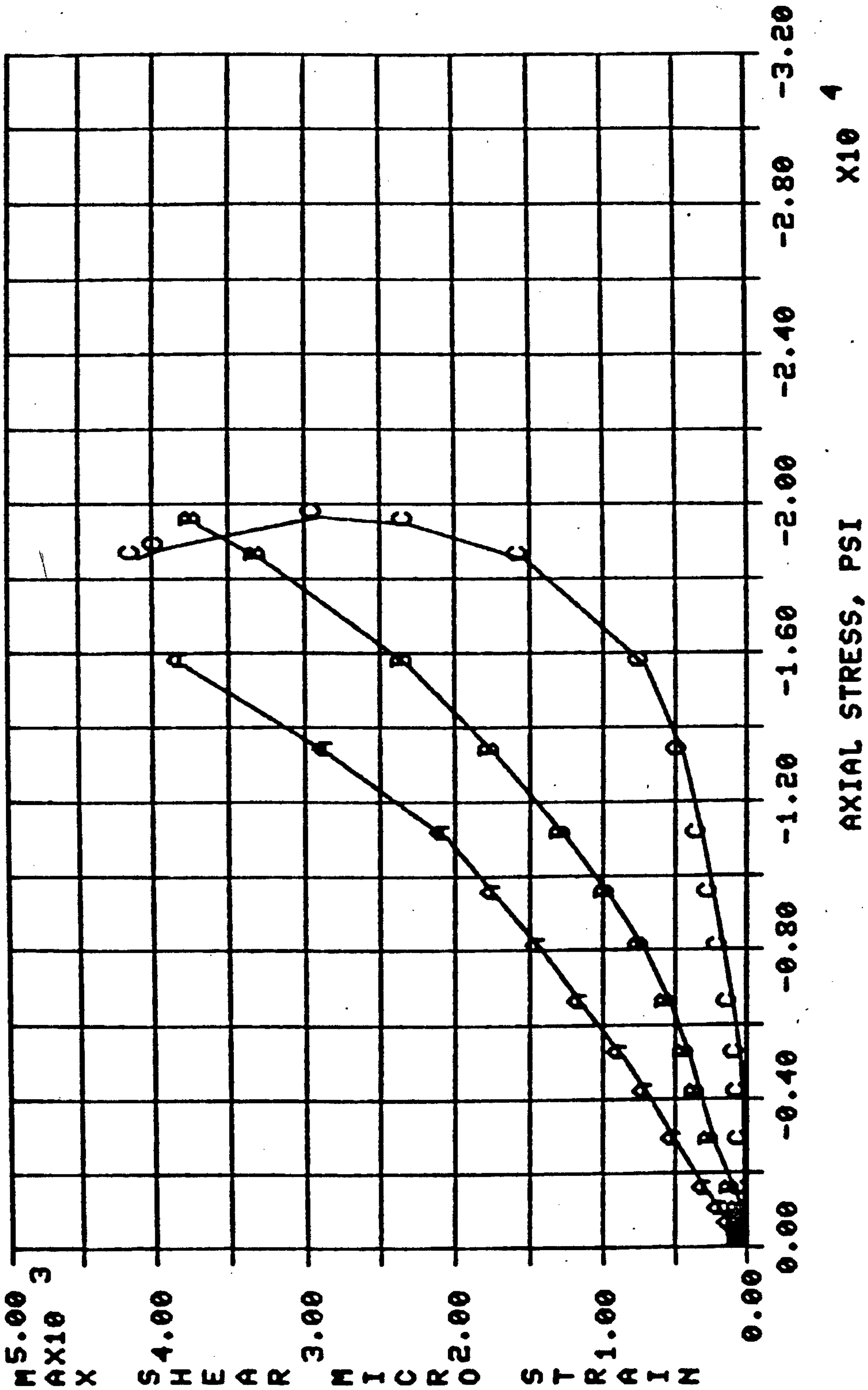


Figure 14 Test 1. Layup ±45° Axial Load Only
Max. Shear, Outside Rosettes

A - Rosette No. 2
B - Rosette No. 3
C - Rosette No. 4

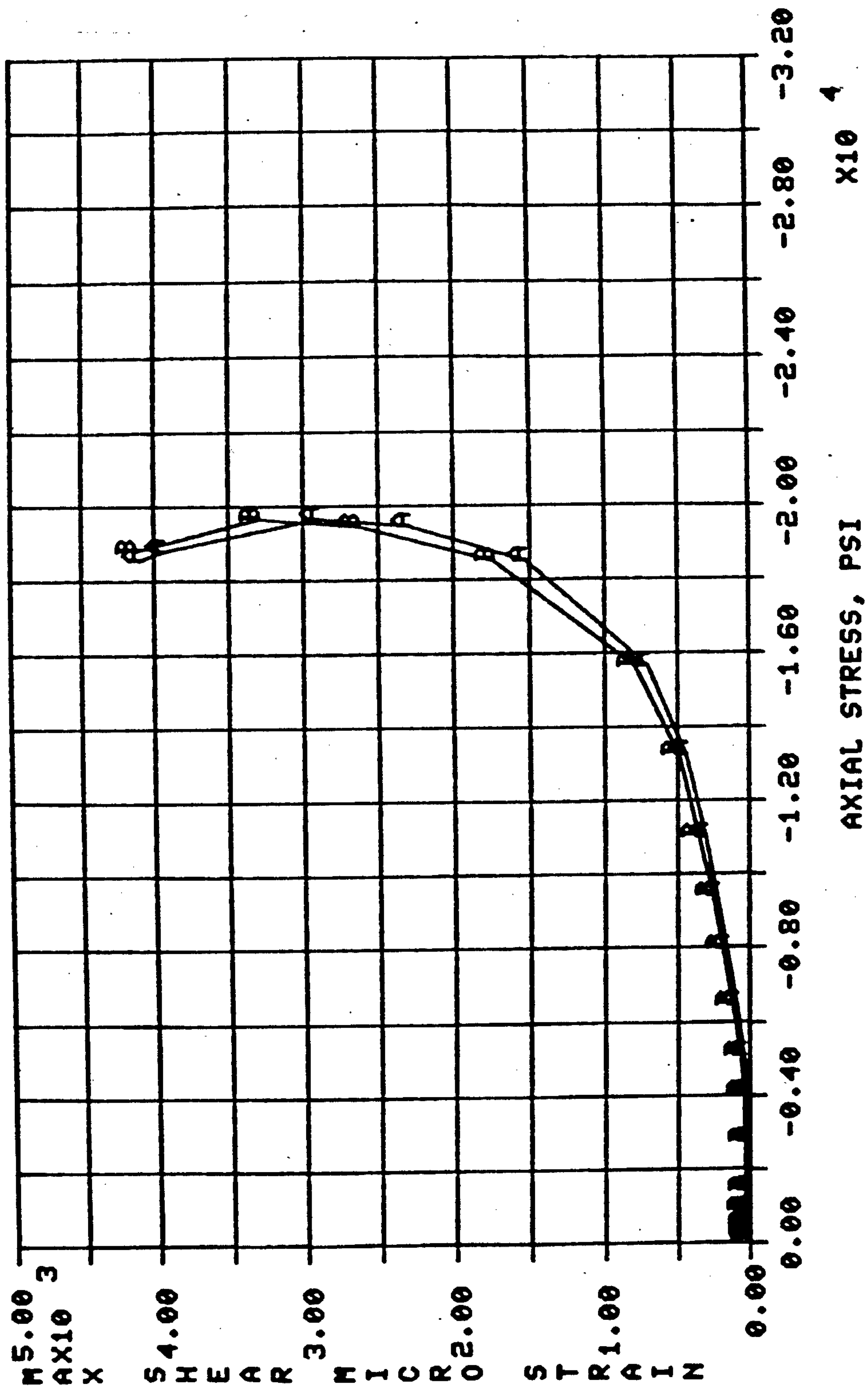


Figure 15 Test 1. Layup ±45° Axial Load Only
Max. Shear, Inside/Outside Rosettes

A - Rosette No. 4 (outside)
B - Rosette No. 5

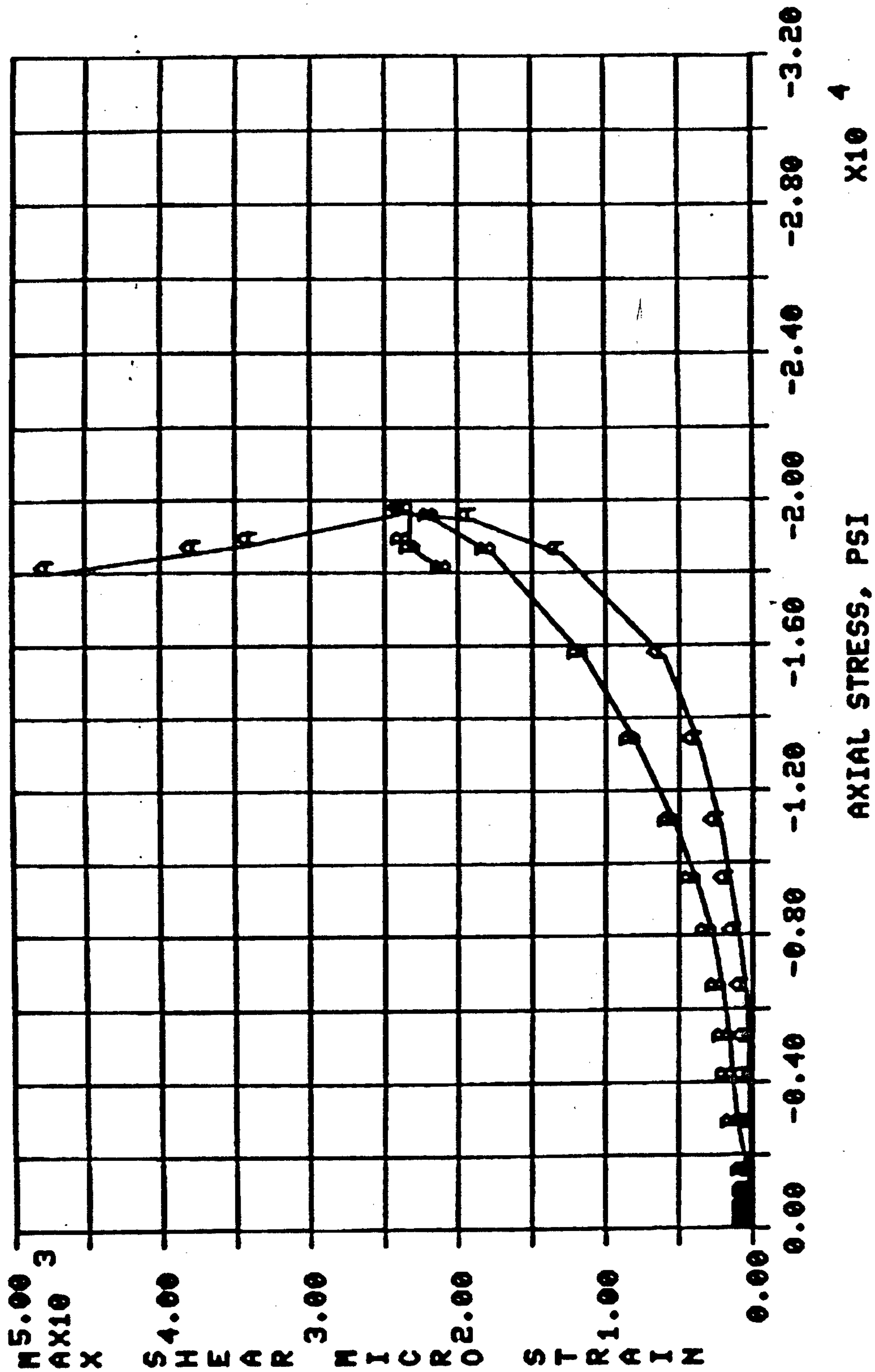


Figure 16 Test 1. Layup ±45° Axial Load Only
Max. Shear Response, Edge Rosettes

A - Rosette No. 7
B - Rosette No. 8

Test 2 was performed on a specimen with a ply layup of $0^{\circ}/\pm45^{\circ}/90^{\circ}$ under internal pressure. Figures 17, 18 and 19 are comparison plots of axial strain, hoop strain and maximum shear strain, respectively, versus hoop stress for the four gages located at the center of the specimen on the outside surface. These strains show good agreement. Strains were not recorded for this specimen until the hoop stress level reached approximately 16,000 psi. This was presumably due to the data acquisition system operating in the automatic balance mode during the first few data scans. Figures 20, 21 and 22 are comparison plots of axial, hoop and maximum shear strains, respectively, versus hoop stress for the two gages located at the center of the specimen but on opposite surfaces. Figures 23, 24 and 25 present comparison plots of axial, hoop and maximum shear strains, respectively, versus hoop stress for the three gages along the top of the specimen. Two of these gages are at the same location, but on opposite surfaces. Very good agreement was found between the inside and outside gages and the maximum shear strains at all rosette locations were almost identical. Hoop stresses greater than 120,000 psi were produced by the internal pressure and final fracture was catastrophic. The specimen after failure is shown in Figure 26.

Test 3 was using a $\pm45^{\circ}$ ply layup specimen under internal pressure. A 100 pound axial load was applied to the specimen prior to the internal pressure. This axial load was kept constant throughout the testing. Data was recorded at only one scan during this test. Figures 27, 28 and 29 present comparisons for axial, hoop and maximum shear strains, respectively, versus hoop stress for the outside center gages. Figures 30, 31 and 32 are comparison plots for axial, hoop and maximum shear strains, respectively, versus hoop stress for the gage locations at the center of the specimen, but on opposite surfaces. Figures 33, 34 and 35 present the comparison plots for

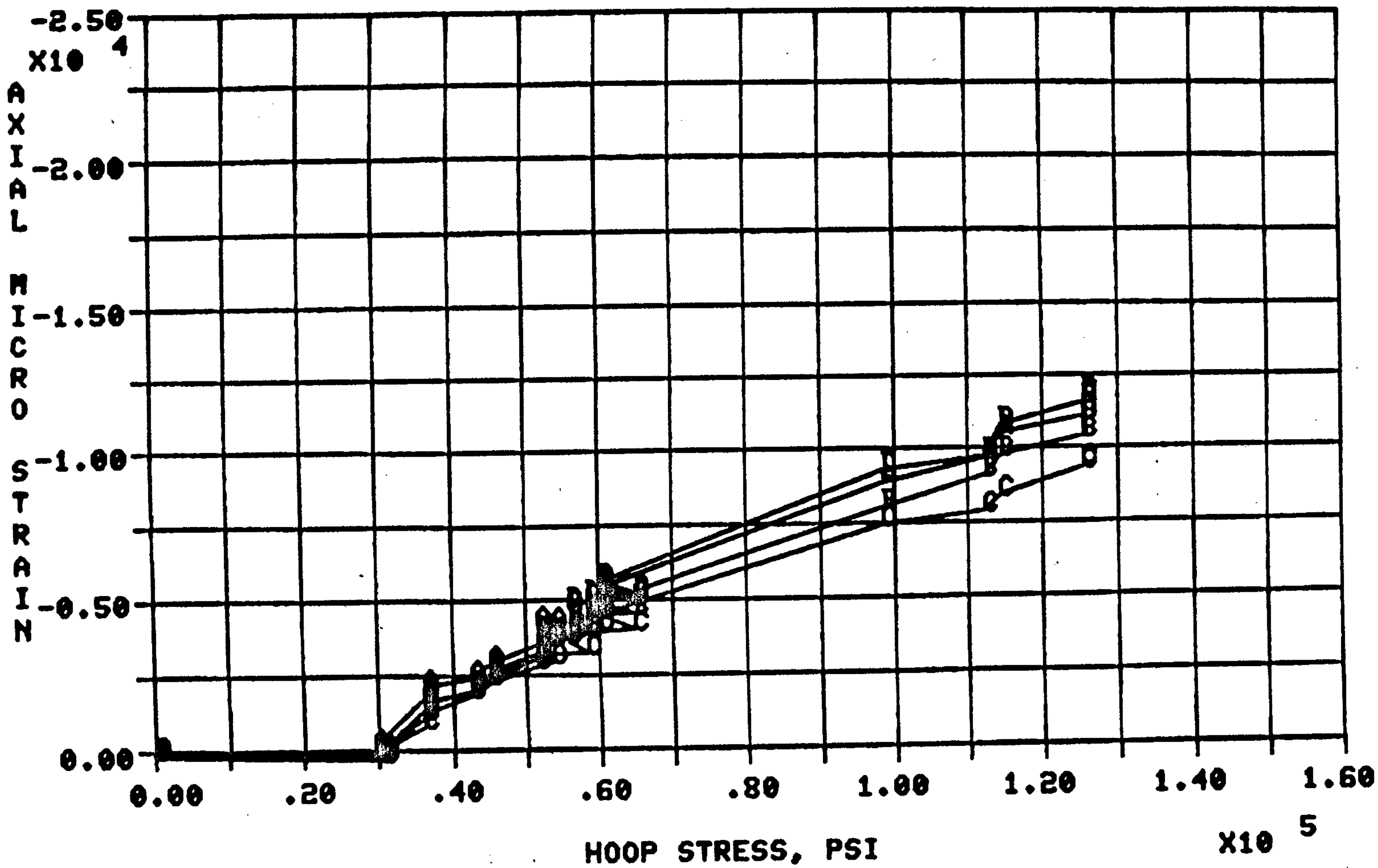


Figure 17 Test 2. Layup 0°/±45°/90° Int.
Pressure Axial Response, Outside Rosettes

A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4

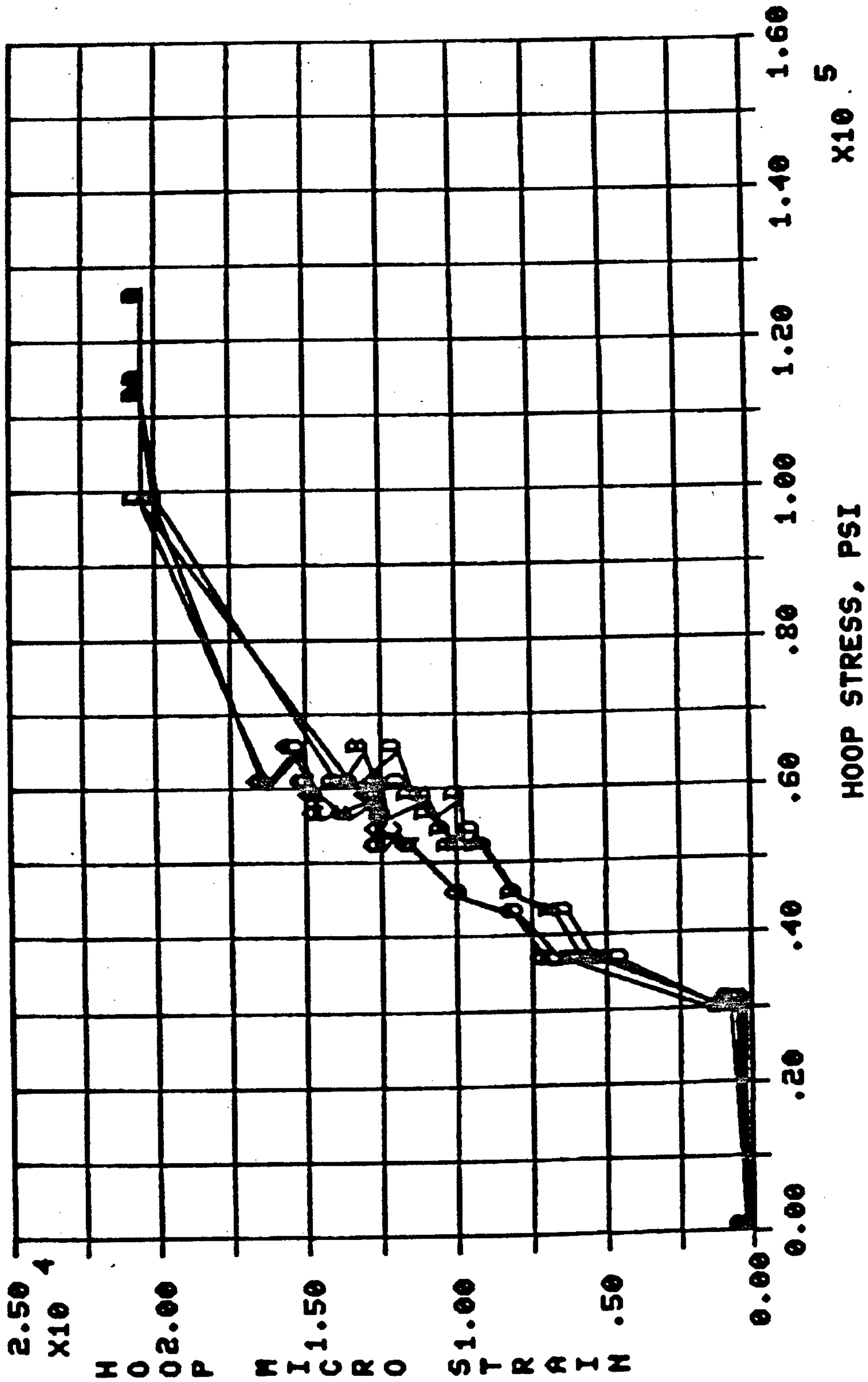


Figure 18 Test 2. Layup 0°/±45°/90° Int. Pressure Hoop Response, Outside Rosettes

A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4

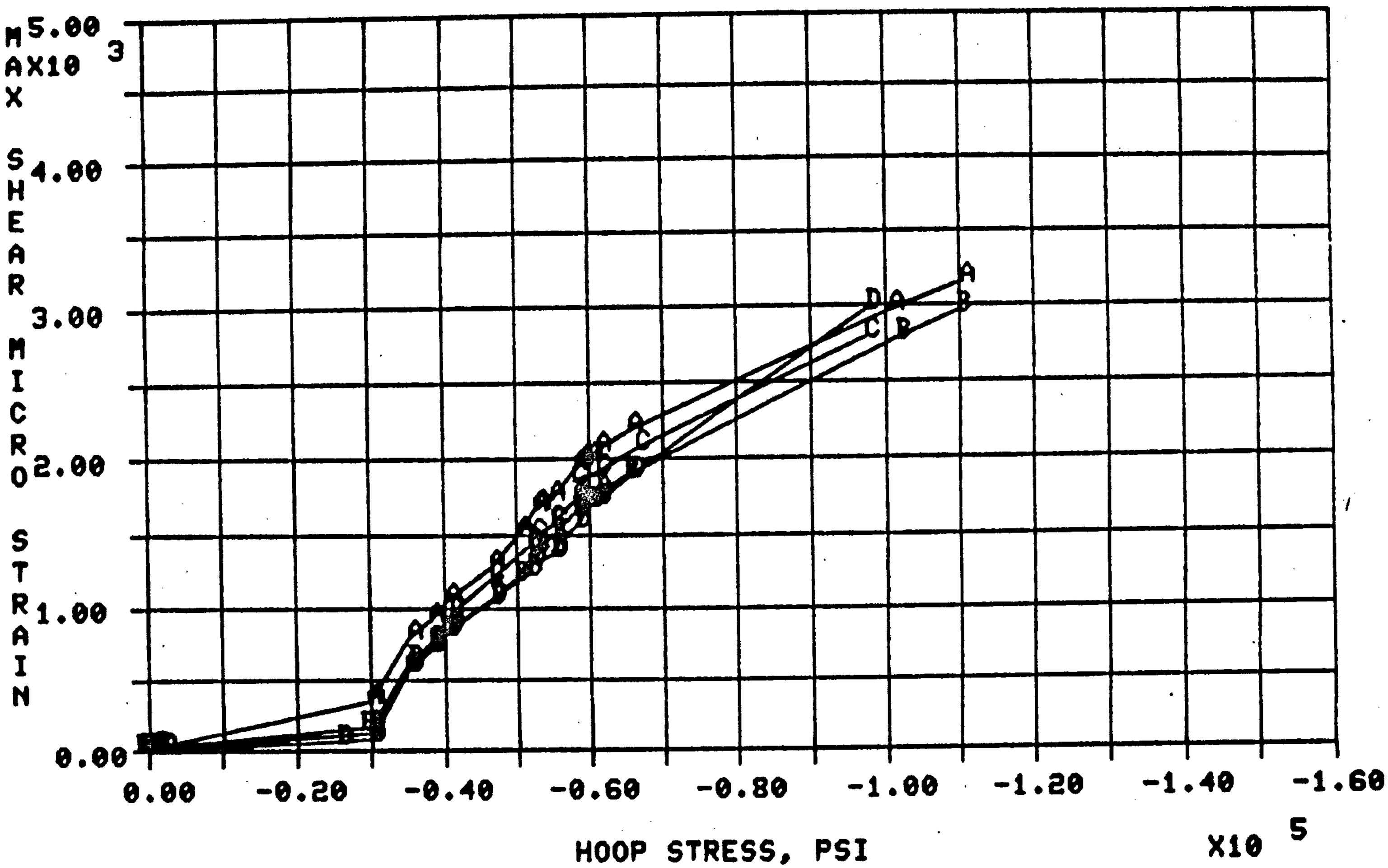


Figure 19 Test 2. Layup 0°/±45°/90° Int. Pressure
Max. Shear, Outside Rosettes

A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4

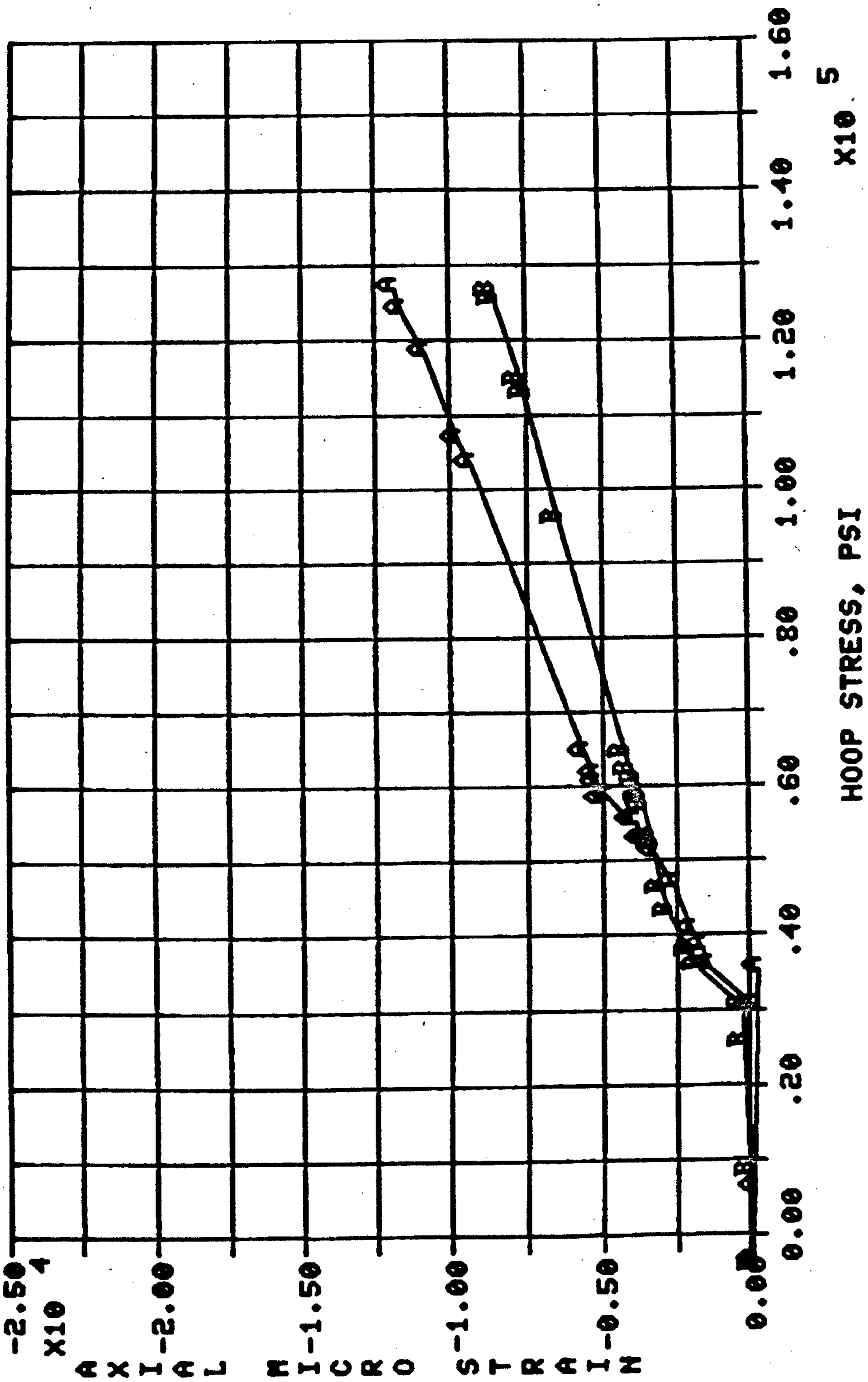


Figure 20 Test 2. Layup 0°/±45°/90° Int. Pressure
Axial Response, Inside/Outside Rosettes
Least Squares Fit

A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)

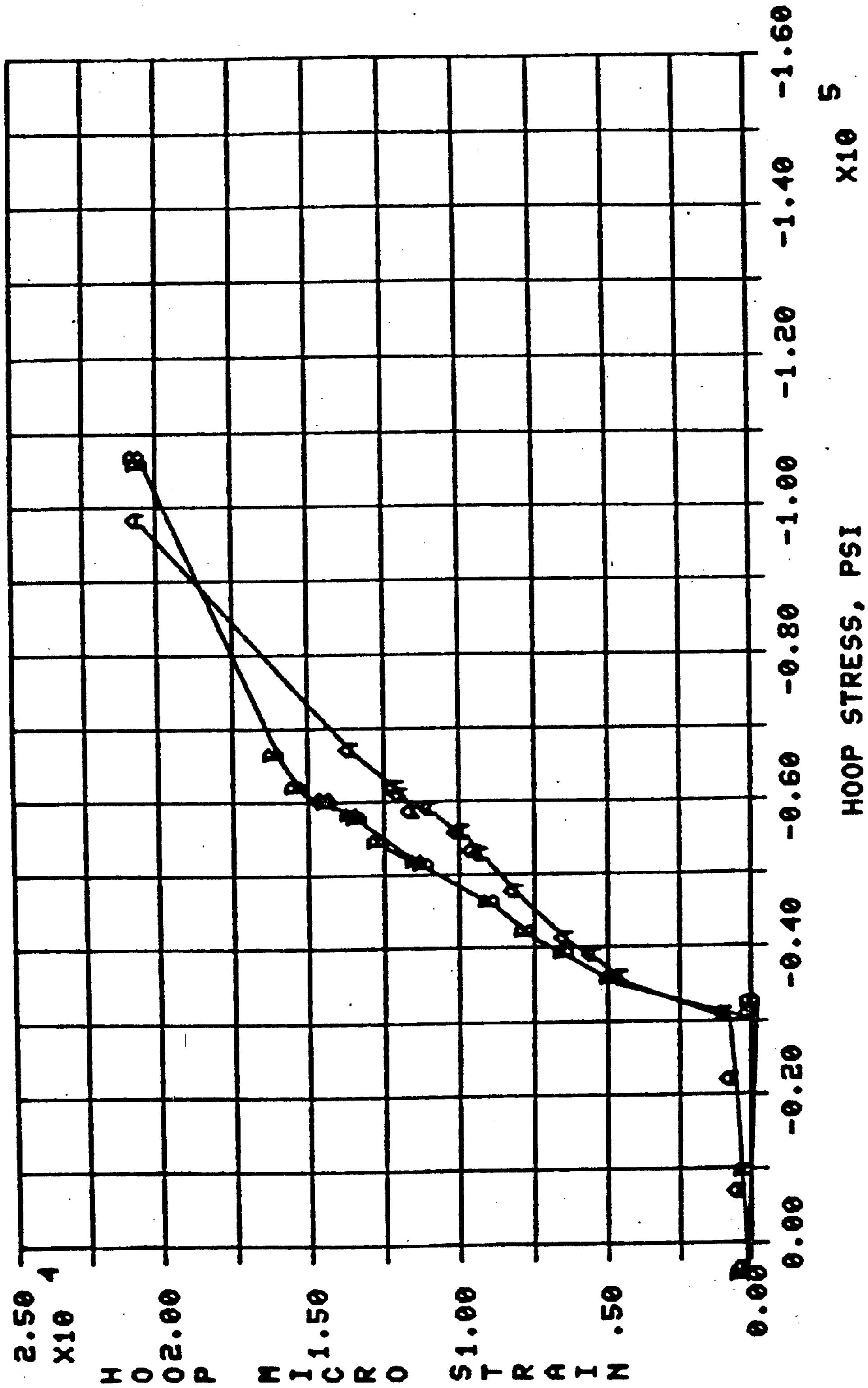


Figure 21 Test 2. Layup 0°/±45°/90° Int. Pressure Hoop Response, Inside/Outside Rosettes

A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)

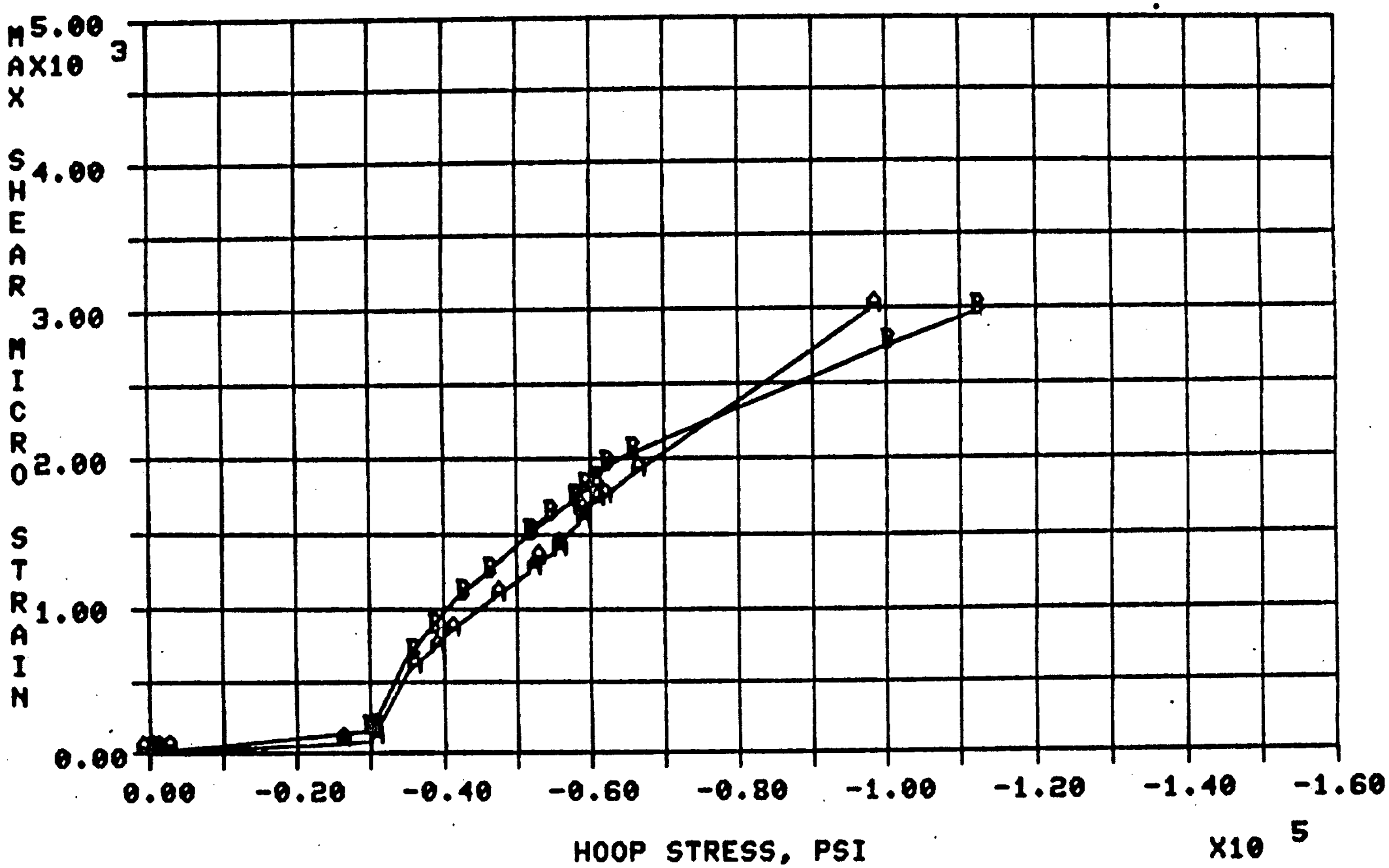


Figure 22 Test 2. Layup 0°/±45°/90° Int. Pressure
Max. Shear, Inside/Outside Rosettes

A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)

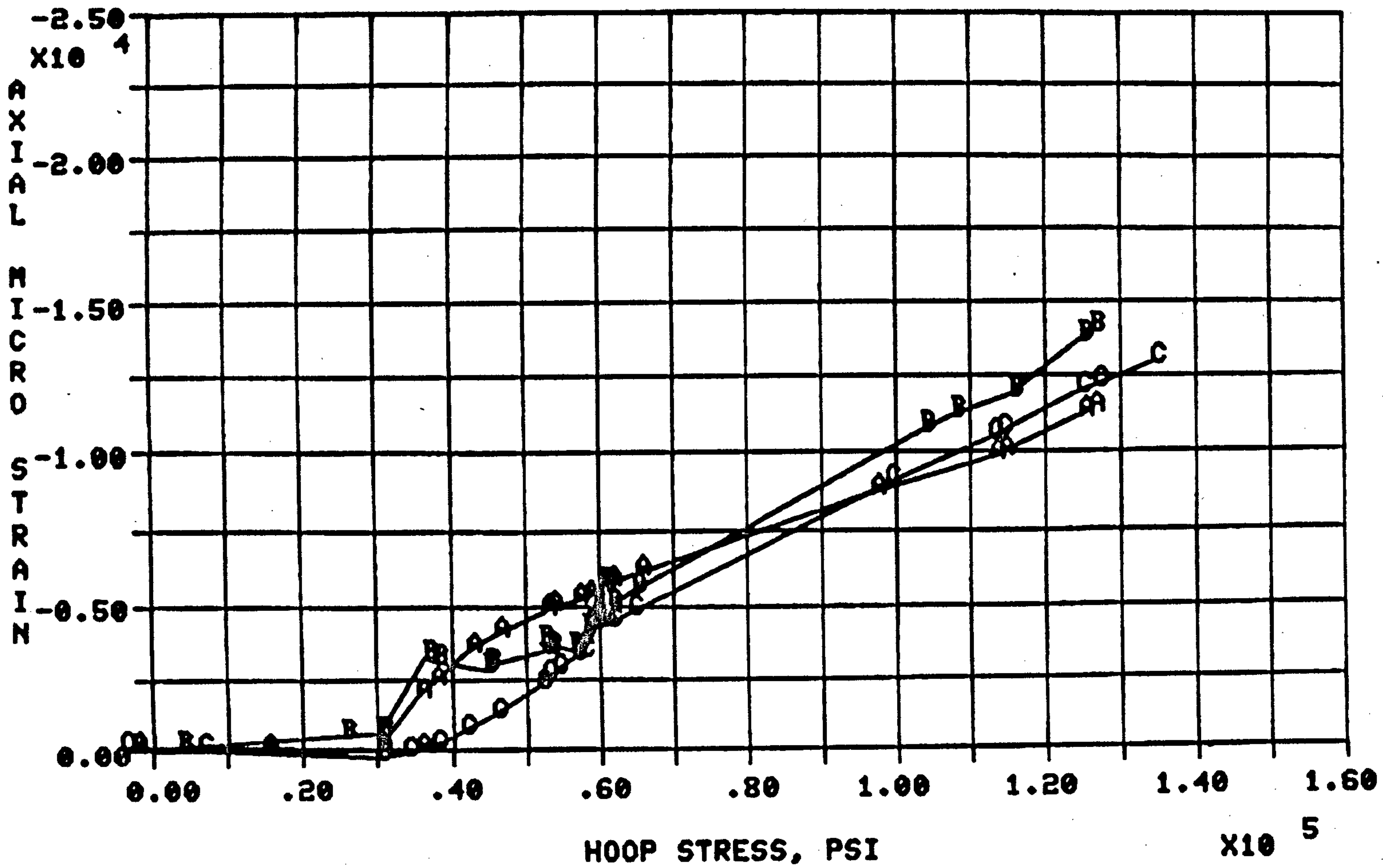


Figure 23    Test 2. Layup 0°/±45°/90° Int. Pressure
Axial Response, Edge Rosettes
Least Squares Fit

A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8

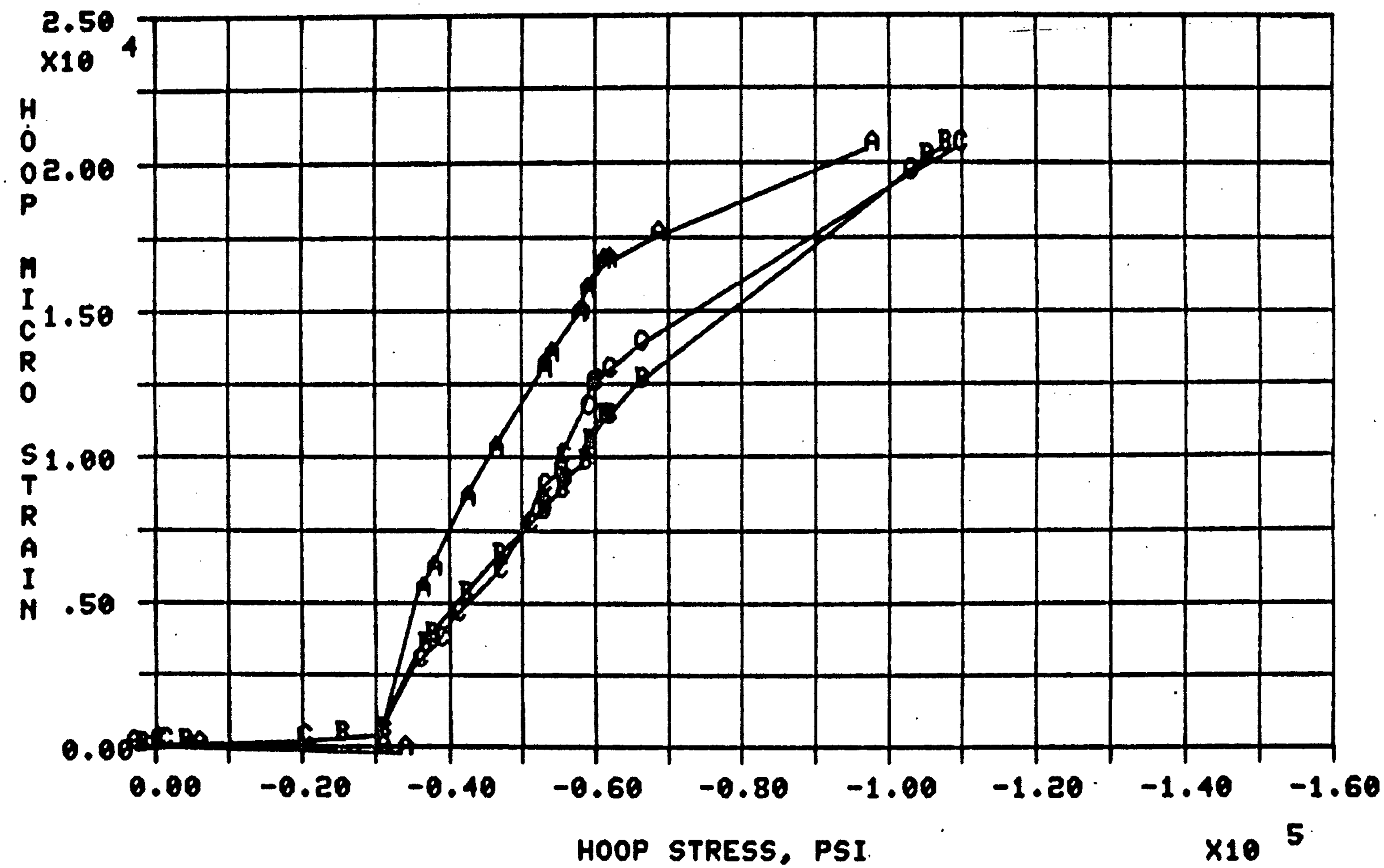


Figure 24 Test 2. Layup 0°/±45°/90° Int. Pressure Hoop Response, Edge Rosettes

A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8

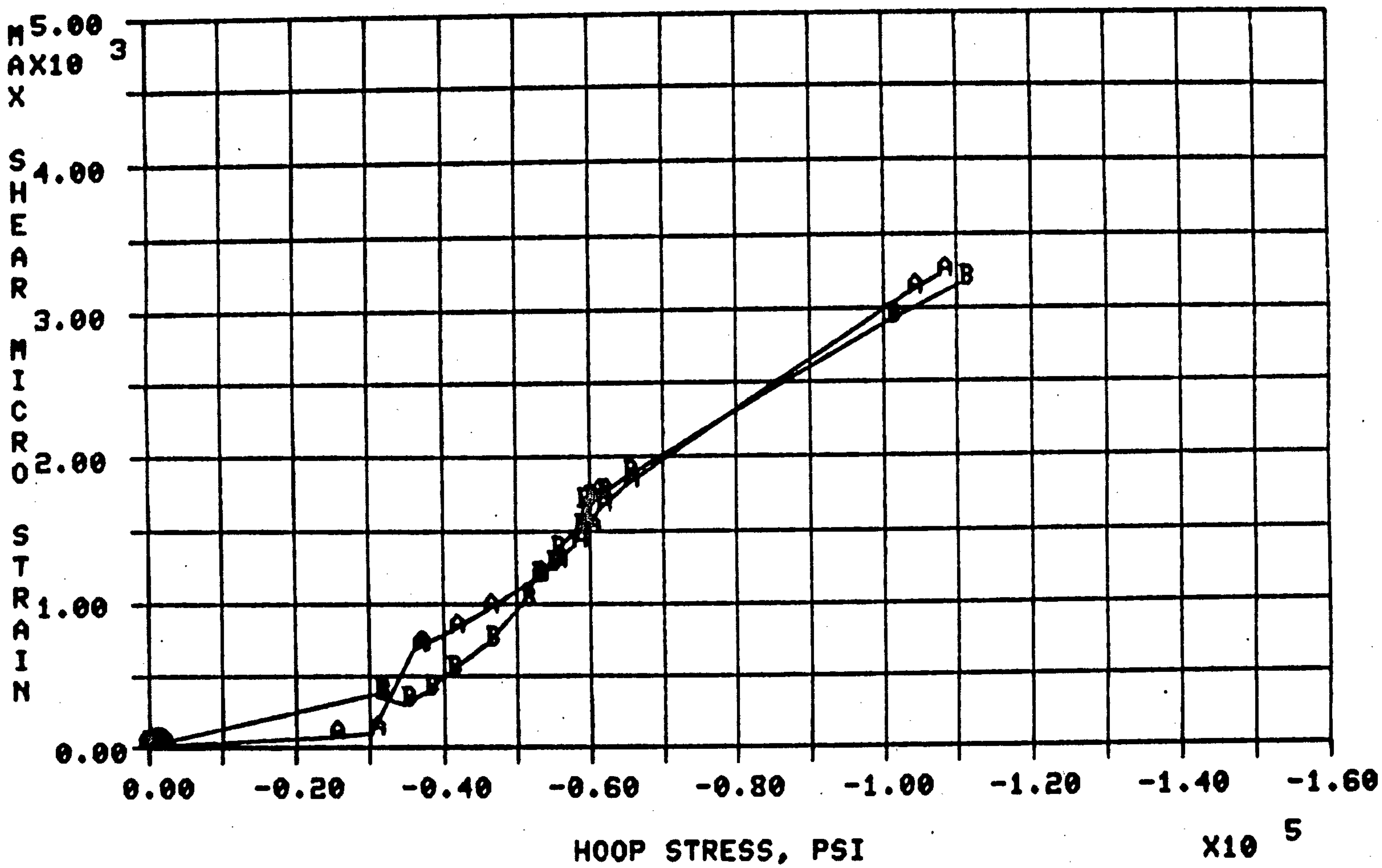


Figure 25 Test 2. Layup 0°/±45°/90° Int. Pressure
Max. Shear, Edge Rosettes

A - Rosette No. 7
B - Rosette No. 8

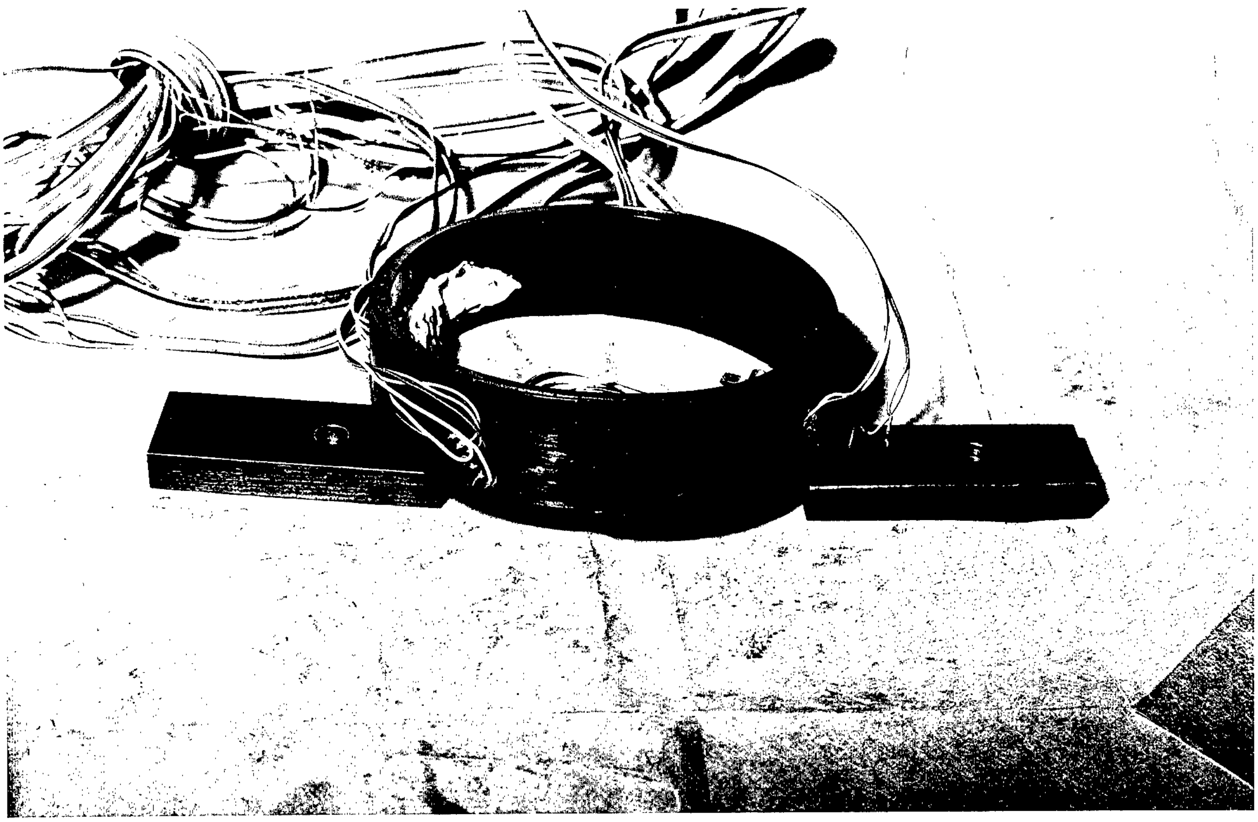

Figure 26 Test Specimen No. 2 After Rupture by Internal Pressure. Ply layup is 0°/±45°/90°.

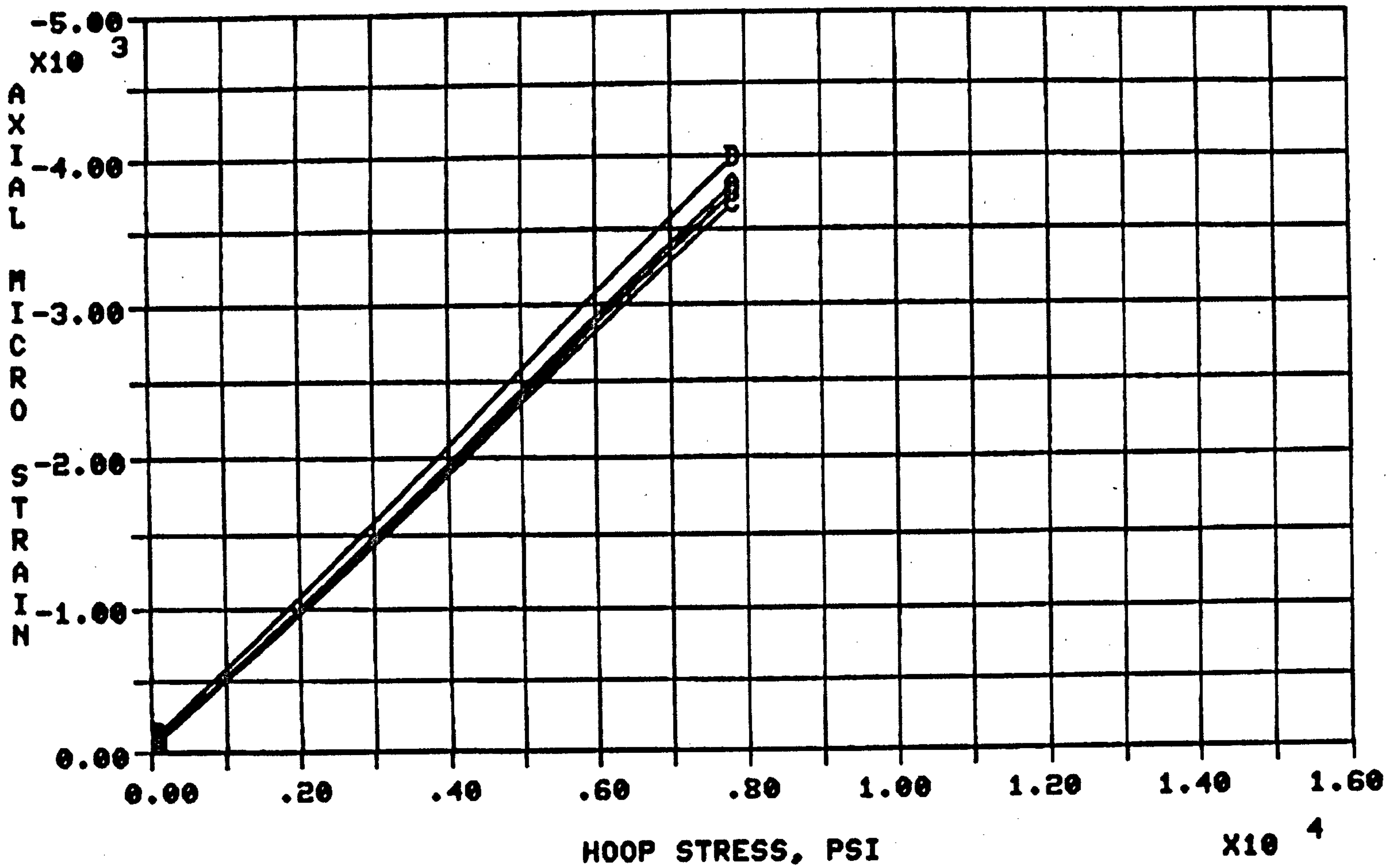


Figure 27 Test 3. ±45° Int. Pressure
Axial Response, Outside Rosettes

A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4

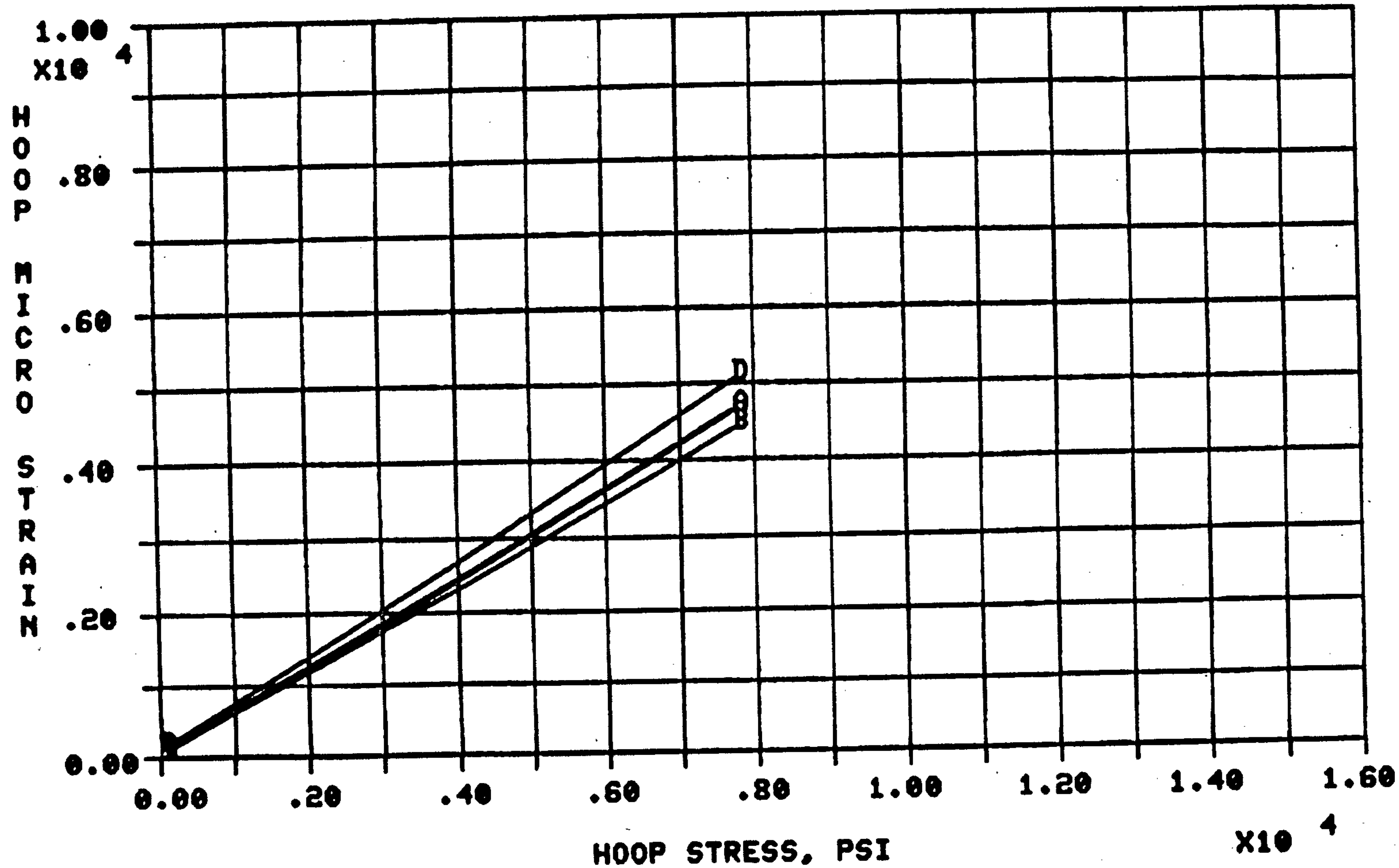


Figure 28 Test 3. ±45° Int. Pressure
Hoop Response, Outside Rosettes

A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4

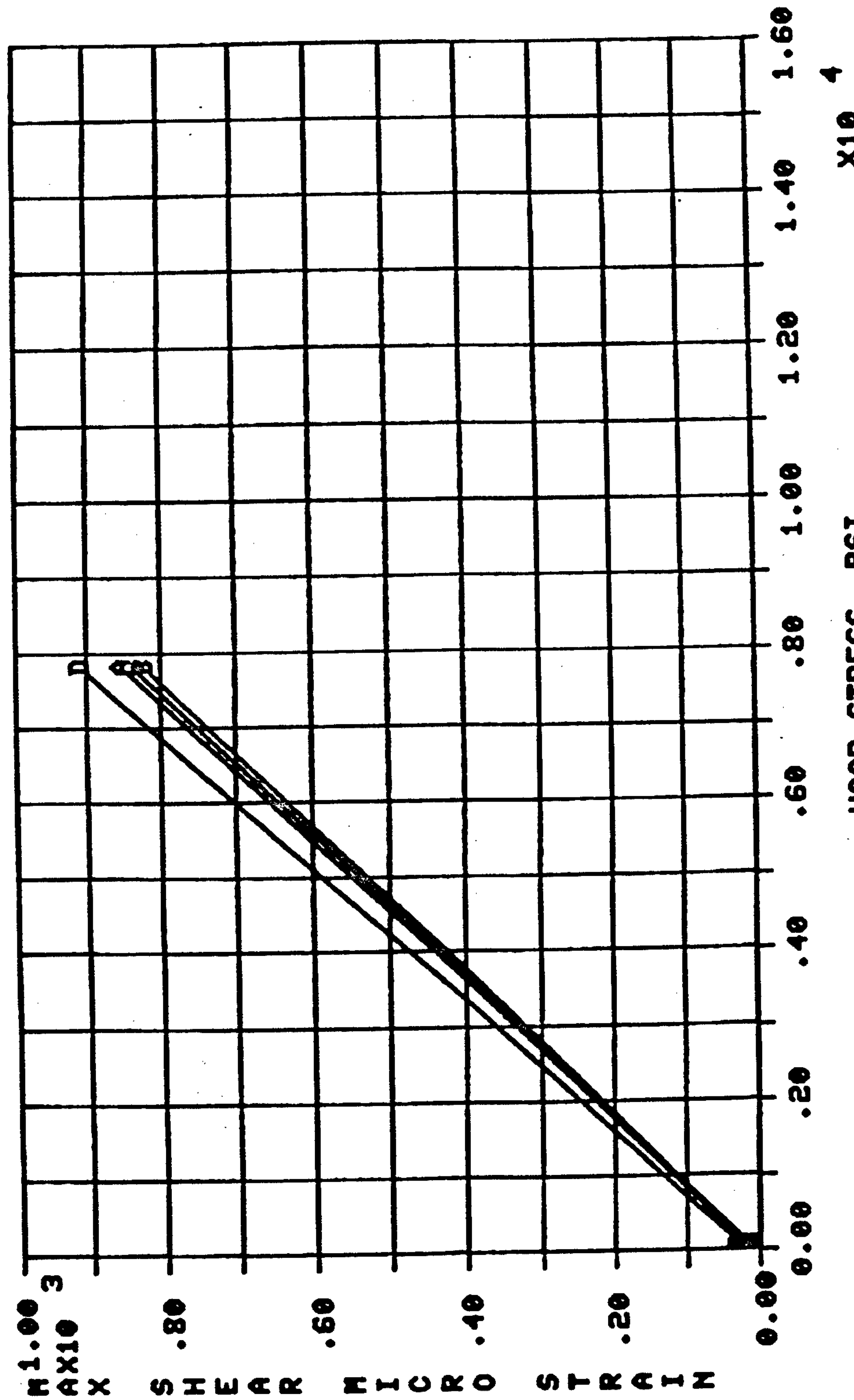


Figure 29 Test 3. ±45° Int. Pressure
Max. Shear, Outside Rosettes

A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4

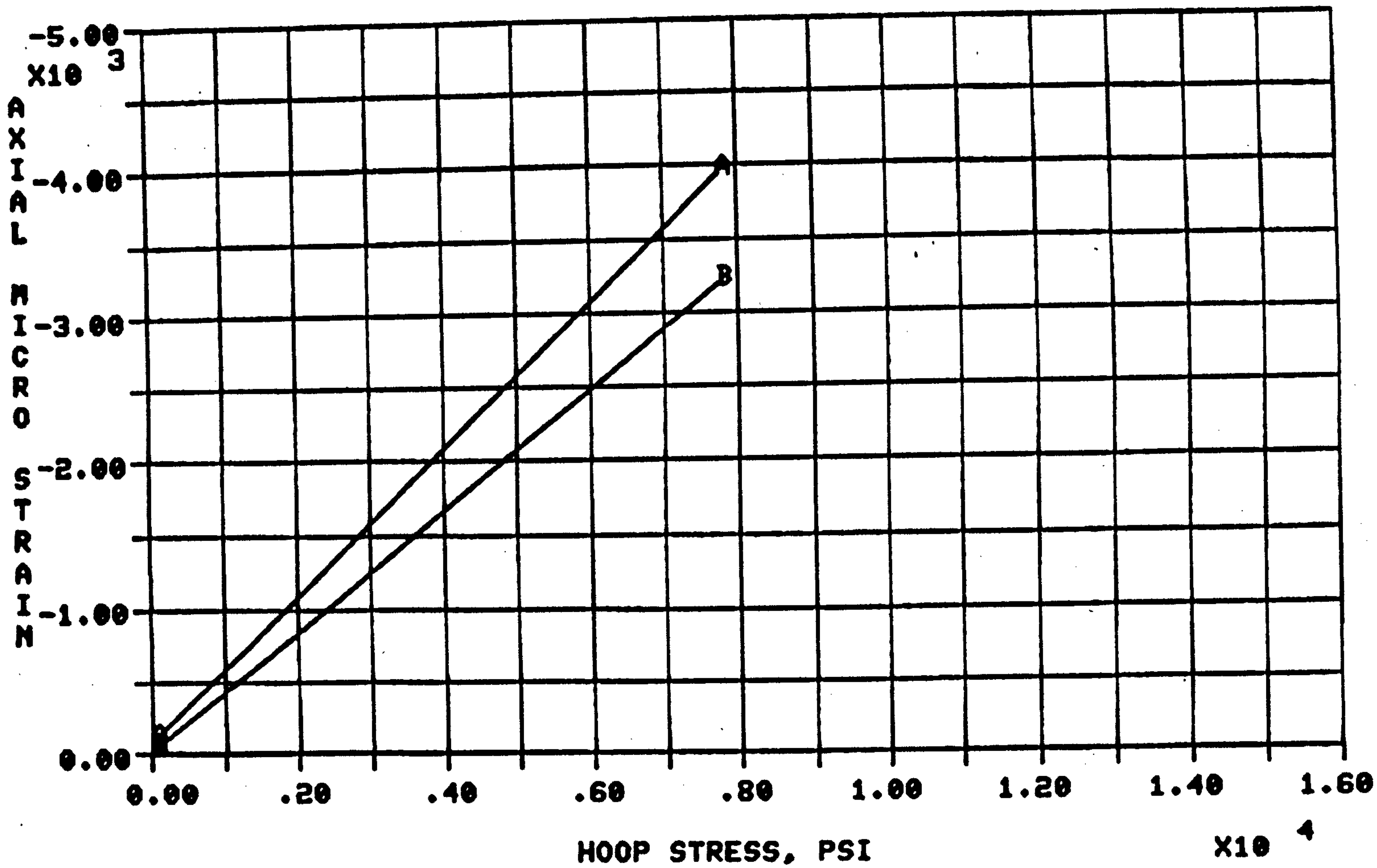


Figure 30 Test 3. ±45° Int. Pressure Axial Response, Inside/Outside Rosettes

A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)

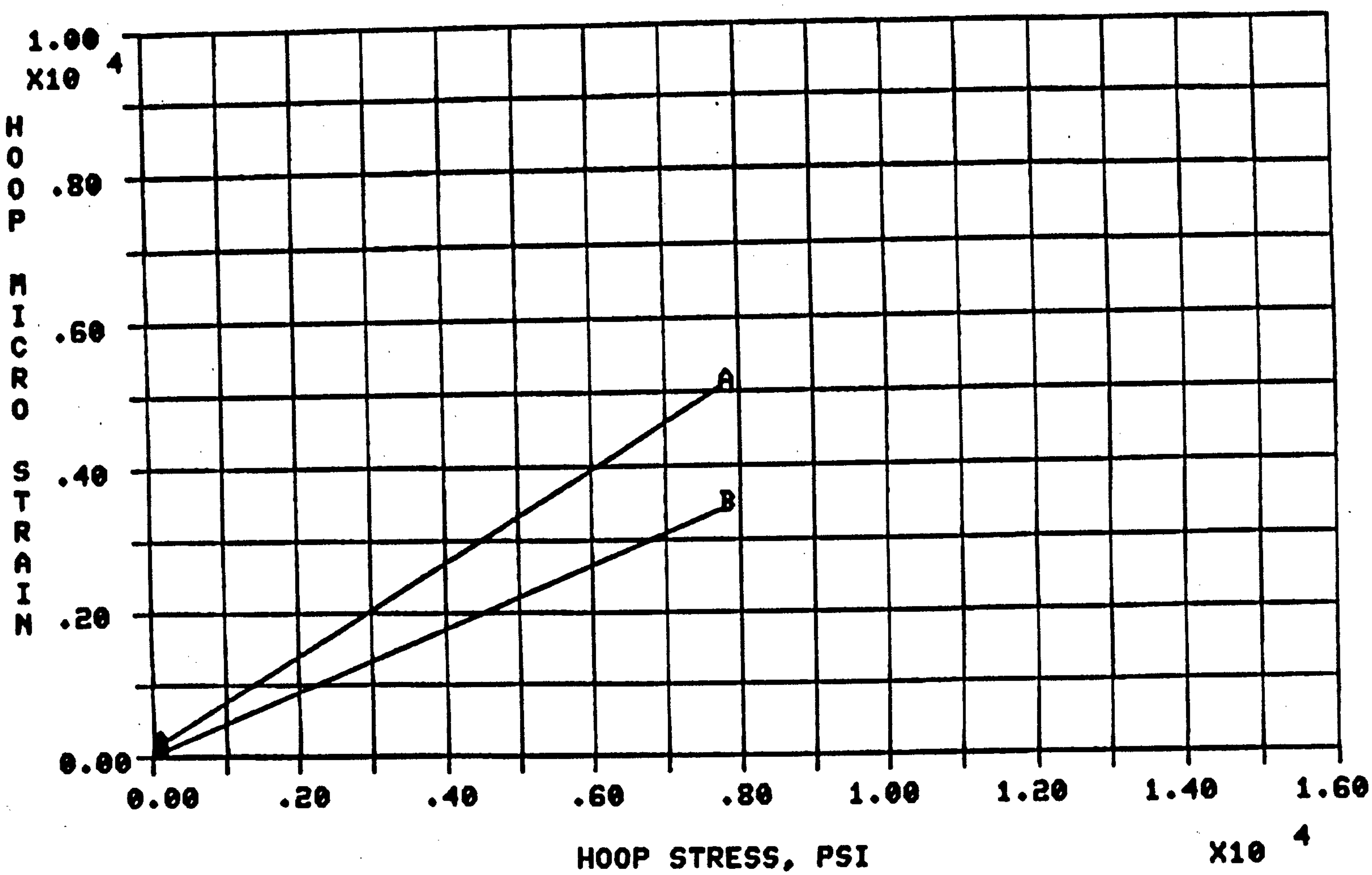


Figure 31 Test 3. ±45° Int. Pressure Hoop Response, Inside/Outside Rosettes

A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)

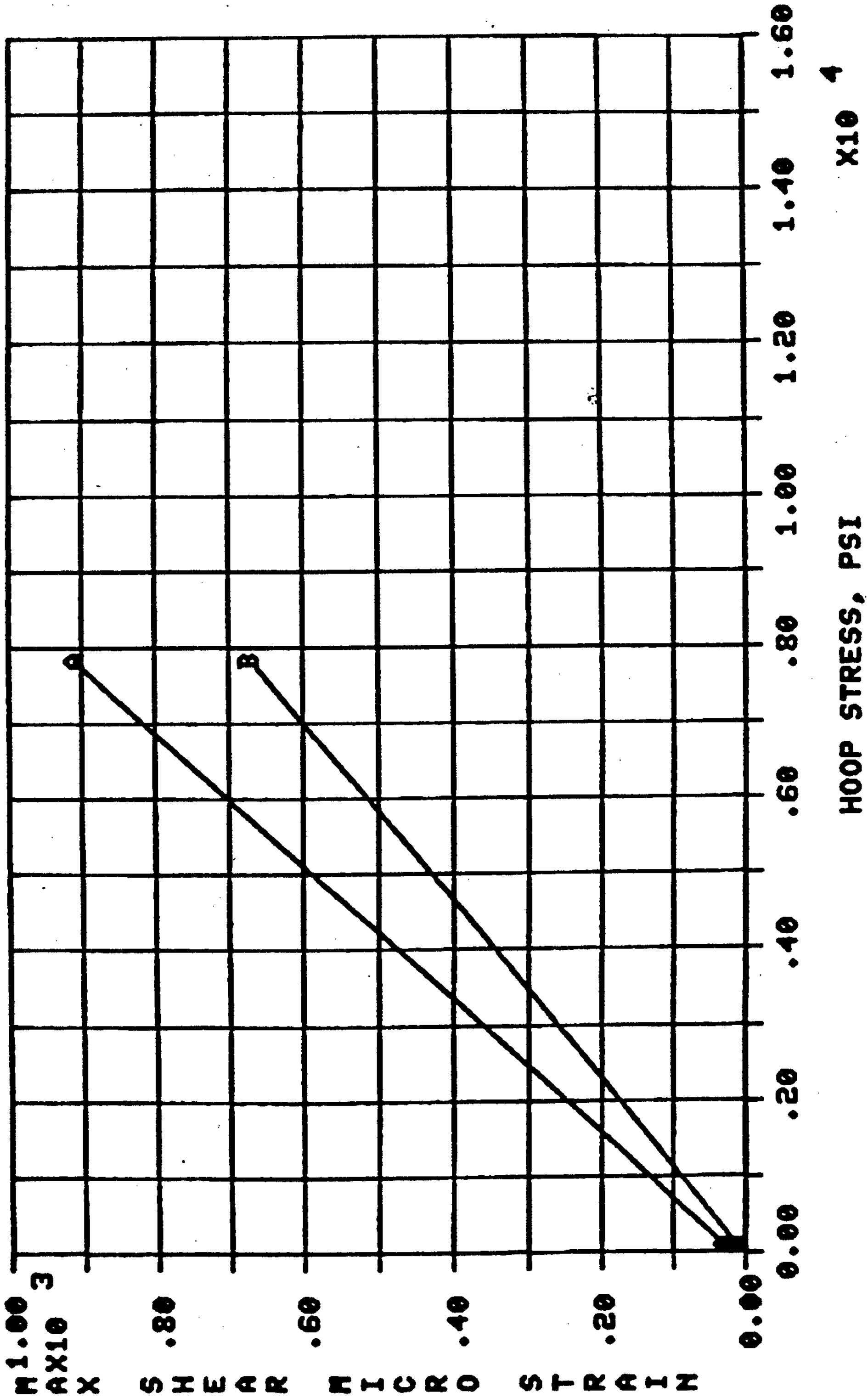


Figure 32 Test 3. ±45° Int. Pressure Max. Shear, Inside/Outside Rosettes

A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)

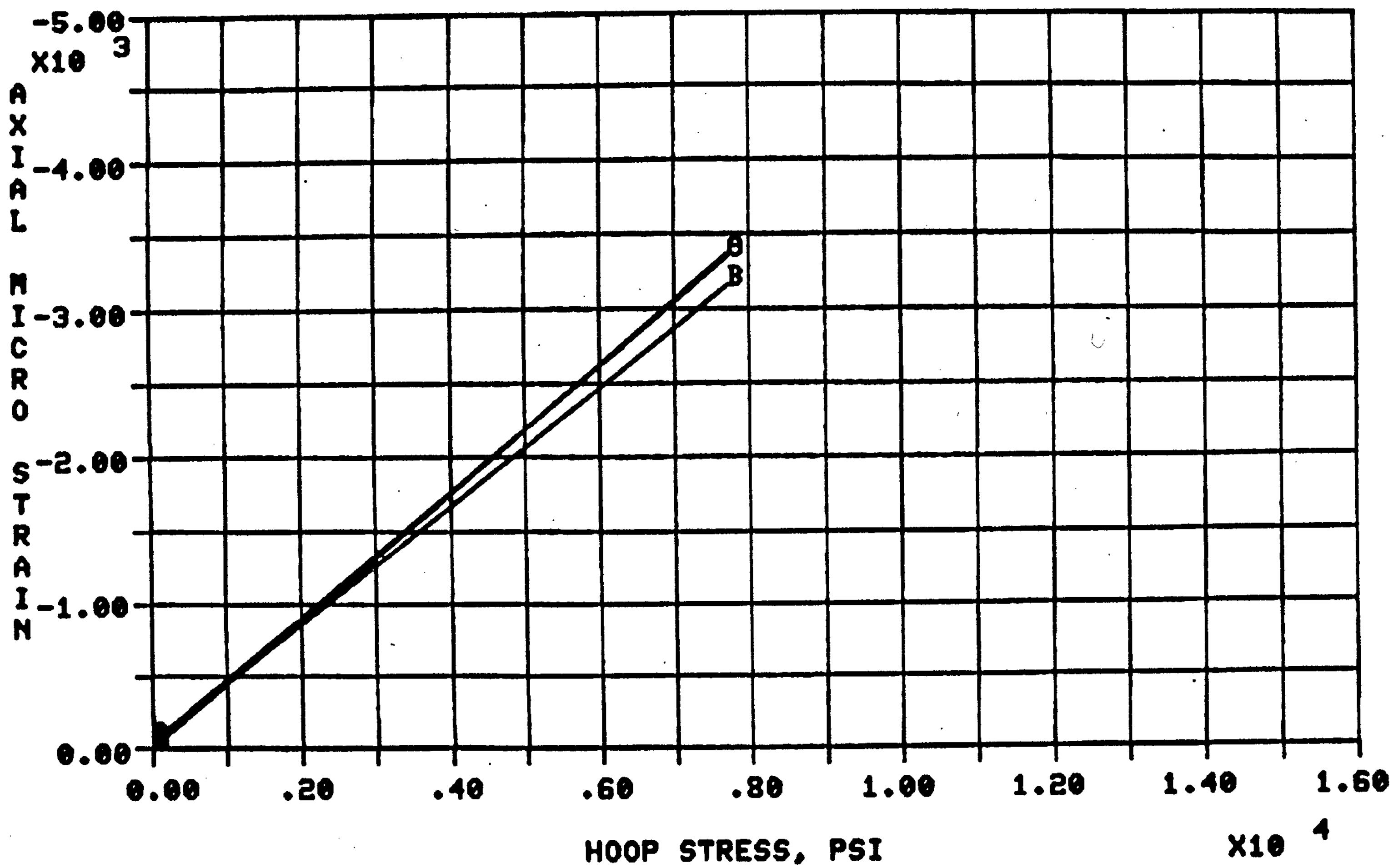


Figure 33 Test 3. ±45° Int. Pressure
Axial Response, Edge Rosettes

A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8

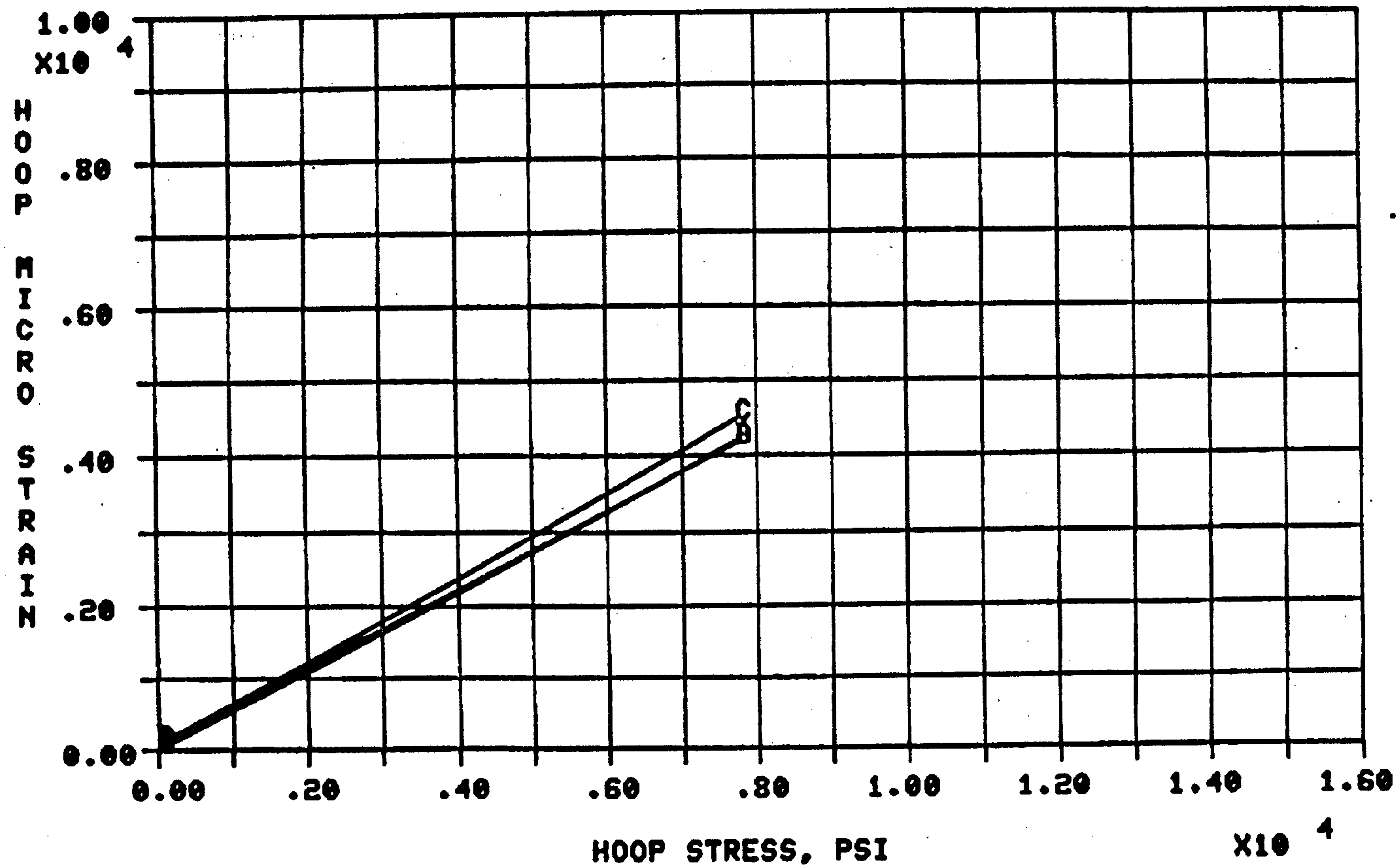


Figure 34 Test 3. ±45° Int. Pressure
Hoop Response, Edge Rosettes

A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8

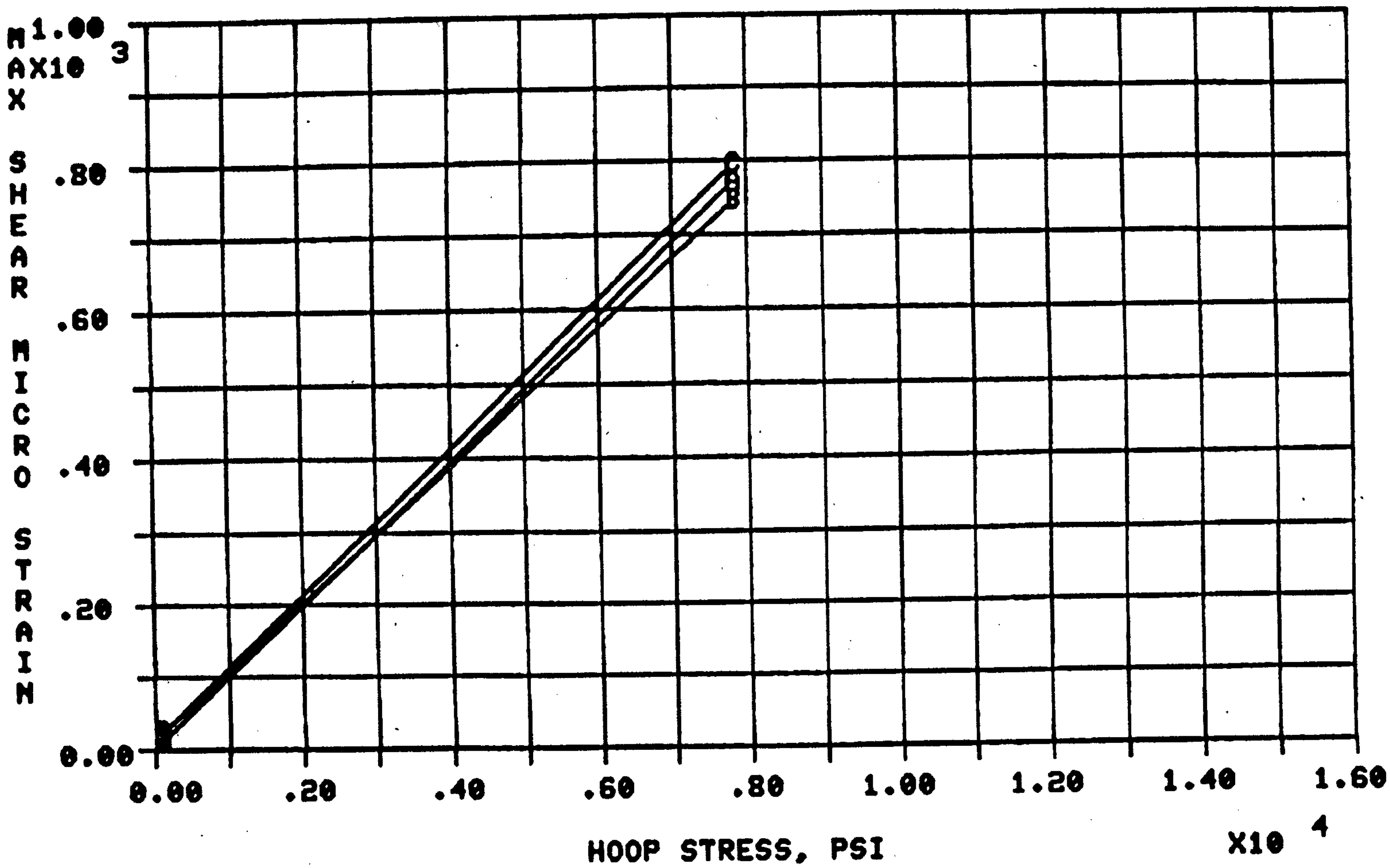


Figure 35 Test 3. ±45° Int. Pressure
Max. Shear, Edge Rosettes

A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8

axial, hoop and maximum shear strains, respectively, versus hoop stress for the gage locations along the edge of the specimen. These plots show excellent agreement for axial and hoop strains for all gages located on the outside surface. Figures 30, 31 and 32 show that some bending was occurring. Maximum shear strains at all rosette locations were in very good agreement. Figure 36 shows the specimen after rupture by the internal pressure.

Test 4 consisted of applying three different partial compressions to the same specimen. The specimen layup was ±45°. For the first partial compression, which was designated as Test 4-A, the axial stress was taken to approximately 5,300 psi. The resulting strain versus axial stress curves are given in Figures 37 through 45. During Test 4-B, the axial stress reached 10,800 psi, twice the value of Test 4-A. Figures 46, 47 and 48 present the comparison plots for axial, hoop and maximum shear strains, respectively, for the locations along the outside center of the specimen. Figures 49, 50 and 51 present the corresponding information for the two gages located at the same location but on the inside and outside surfaces. Figures 52, 53 and 54 are comparison plots for the edge locations. Comparing the figures for Test 4-B (Figures 46 through 54) with those of Test 4-A (Figures 37 through 45) shows excellent agreement between the two tests. This indicates the tests were repeatable for this specimen up to at least 5,300 psi axial stress. These two tests show considerable scatter between the four gages located on the outside surface along the center of the specimen. Scatter of data is also seen between the edge gage locations. The comparison between inside and outside gage results (see Figures 49, 50 and 51) shows little bending is occurring at this location. Figures 55, 56 and 57 are comparison plots of axial, hoop and maximum shear strains, respectively, versus axial stress for the locations along the outside

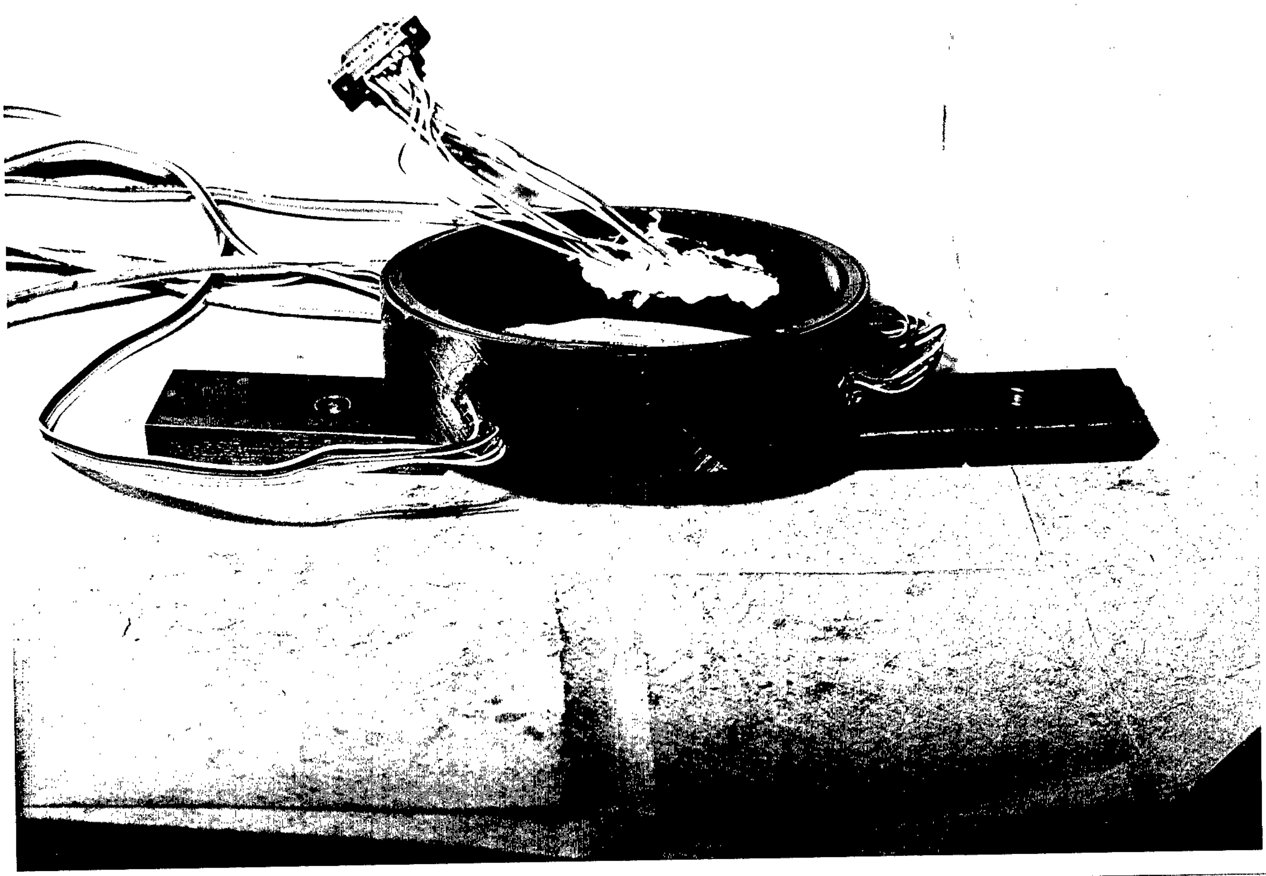

Figure 36 Test Specimen No. 3 After Rupture by Internal Pressure. Ply Layup is ±45°.

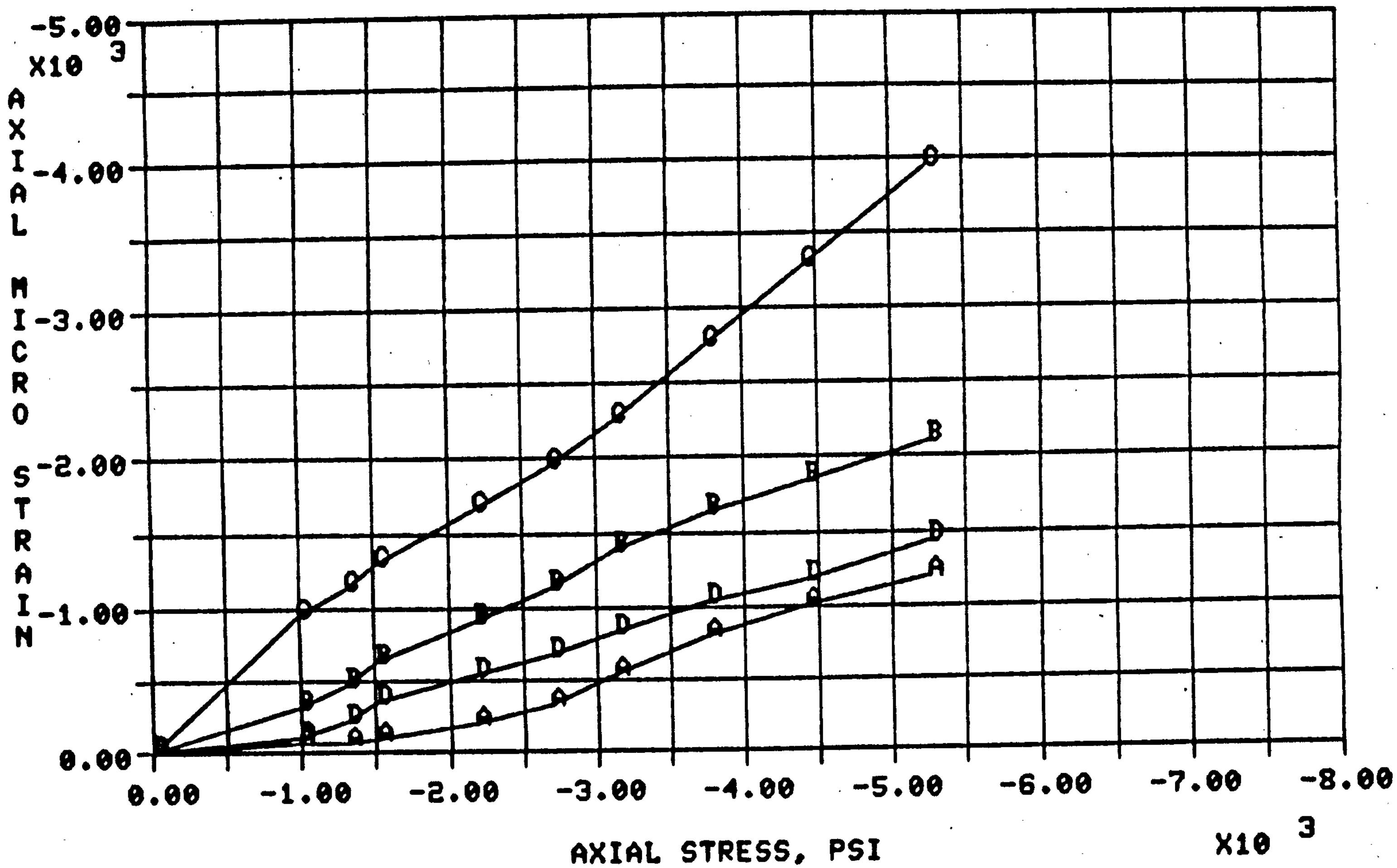


Figure 37 Test 4-A. Layup ±45° Axial Load Only
Axial Response, Outside Rosettes

A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4

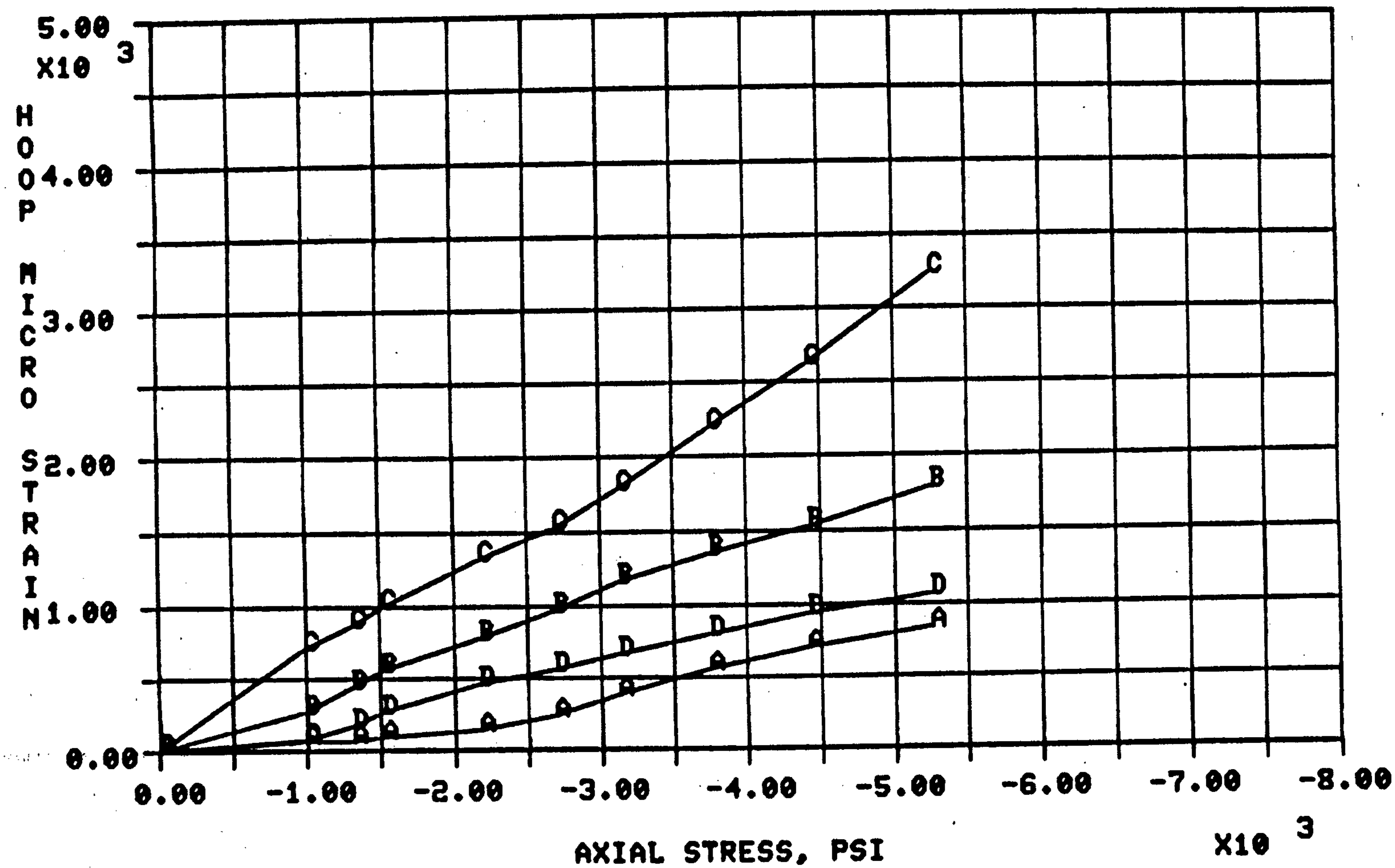


Figure 38 Test 4-A. Layup ±45° Axial Load Only
Hoop Response, Outside Rosettes

A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4

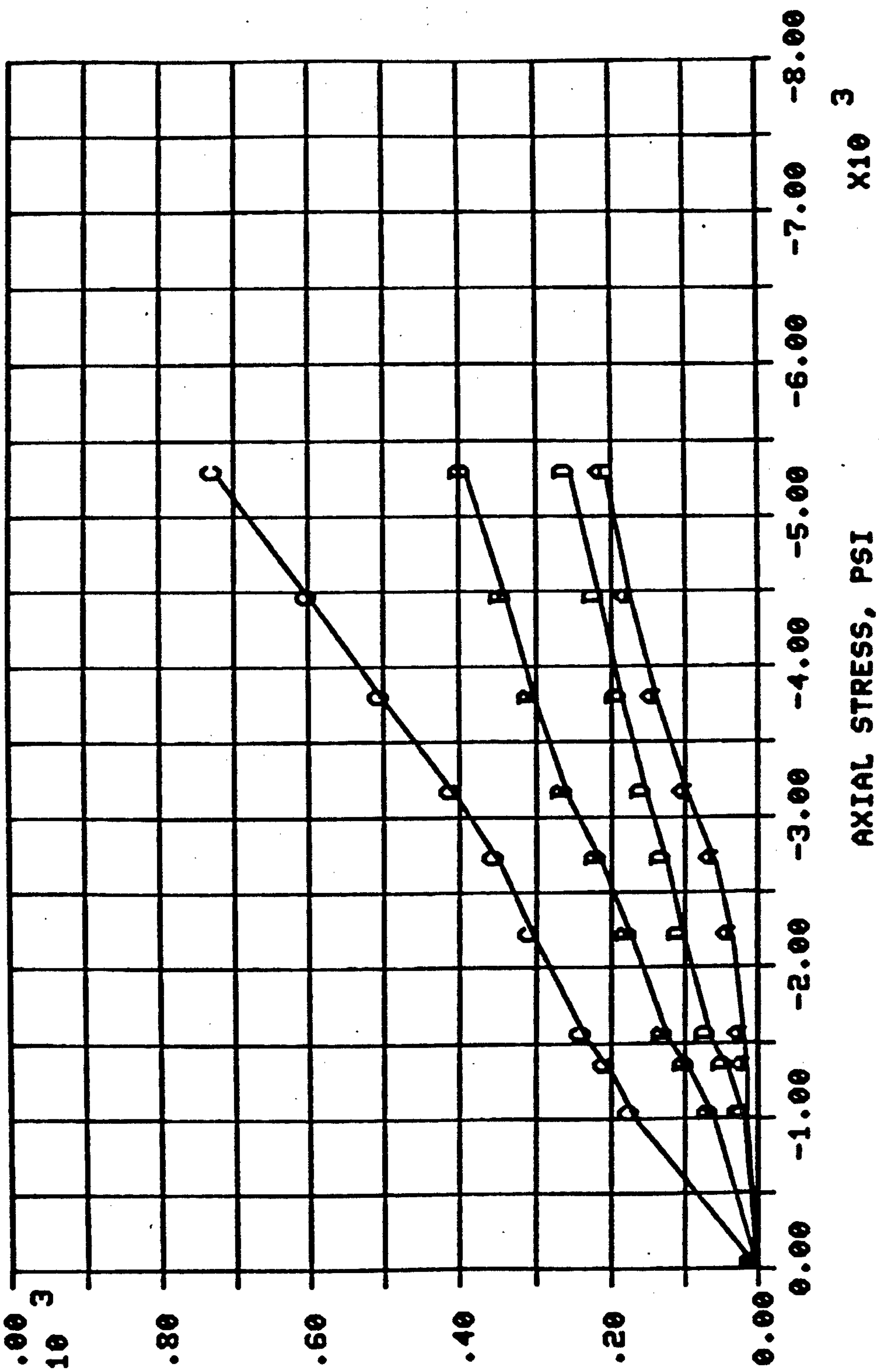


Figure 39 Test 4-A. Layup ±45° Axial Load Only
Max. Shear, Outside Rosettes

A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4

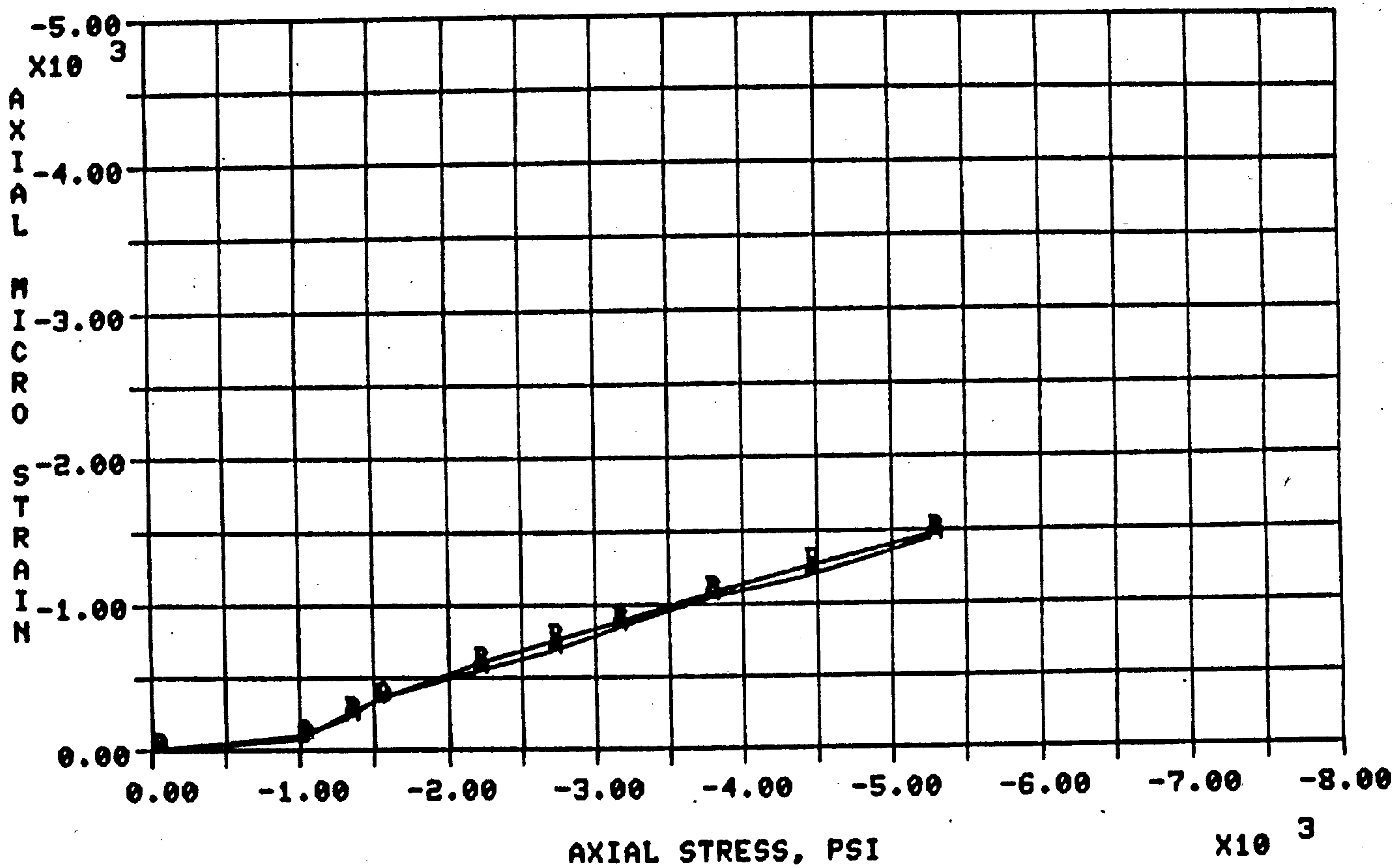


Figure 40 Test 4-A. Layup ±45° Axial Load Only
Axial Response, Inside/Outside Rosettes

A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)

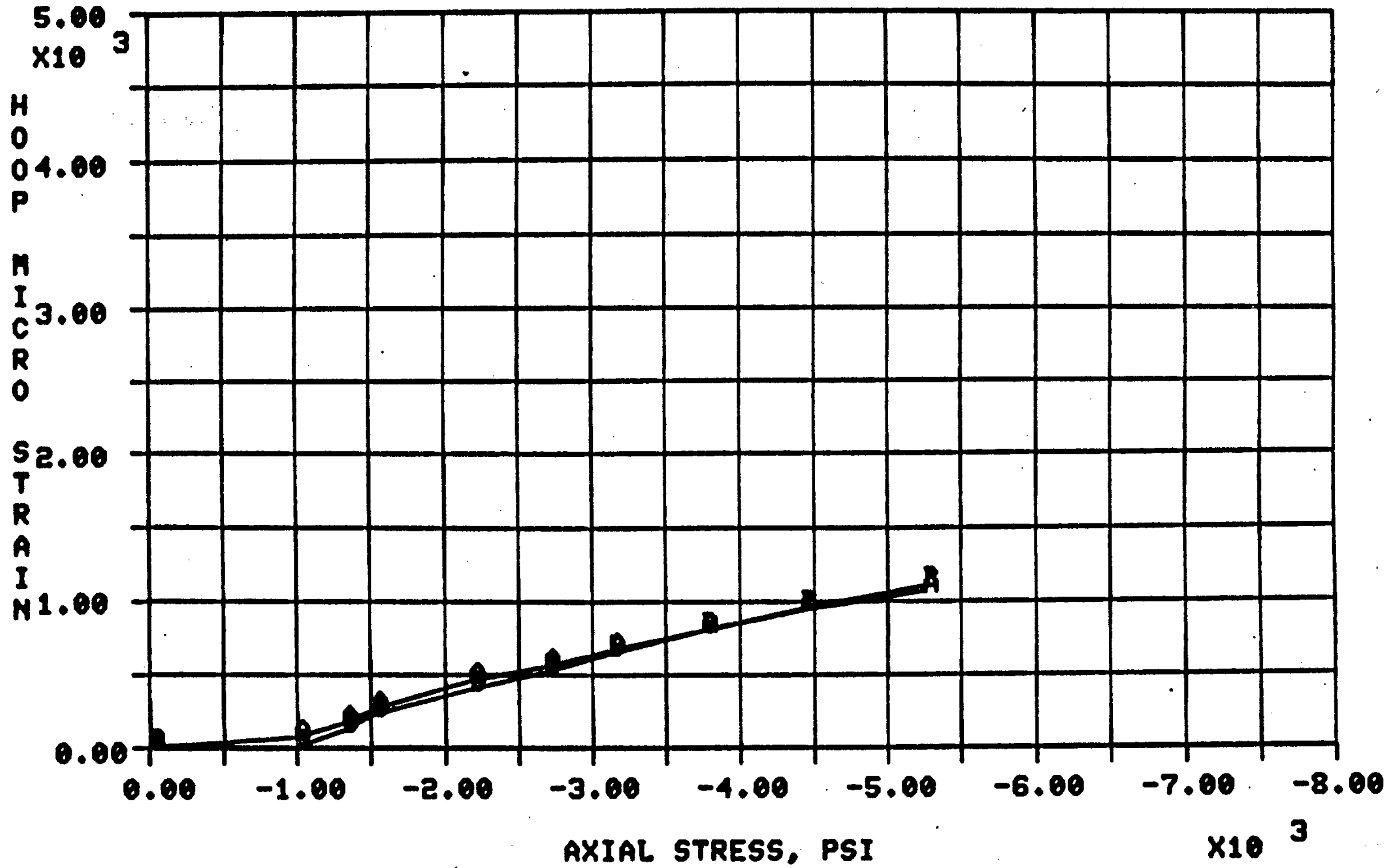


Figure 41 Test 4-A. Layup ±45° Axial Load Only
Hoop Response, Inside/Outside Rosettes

A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)

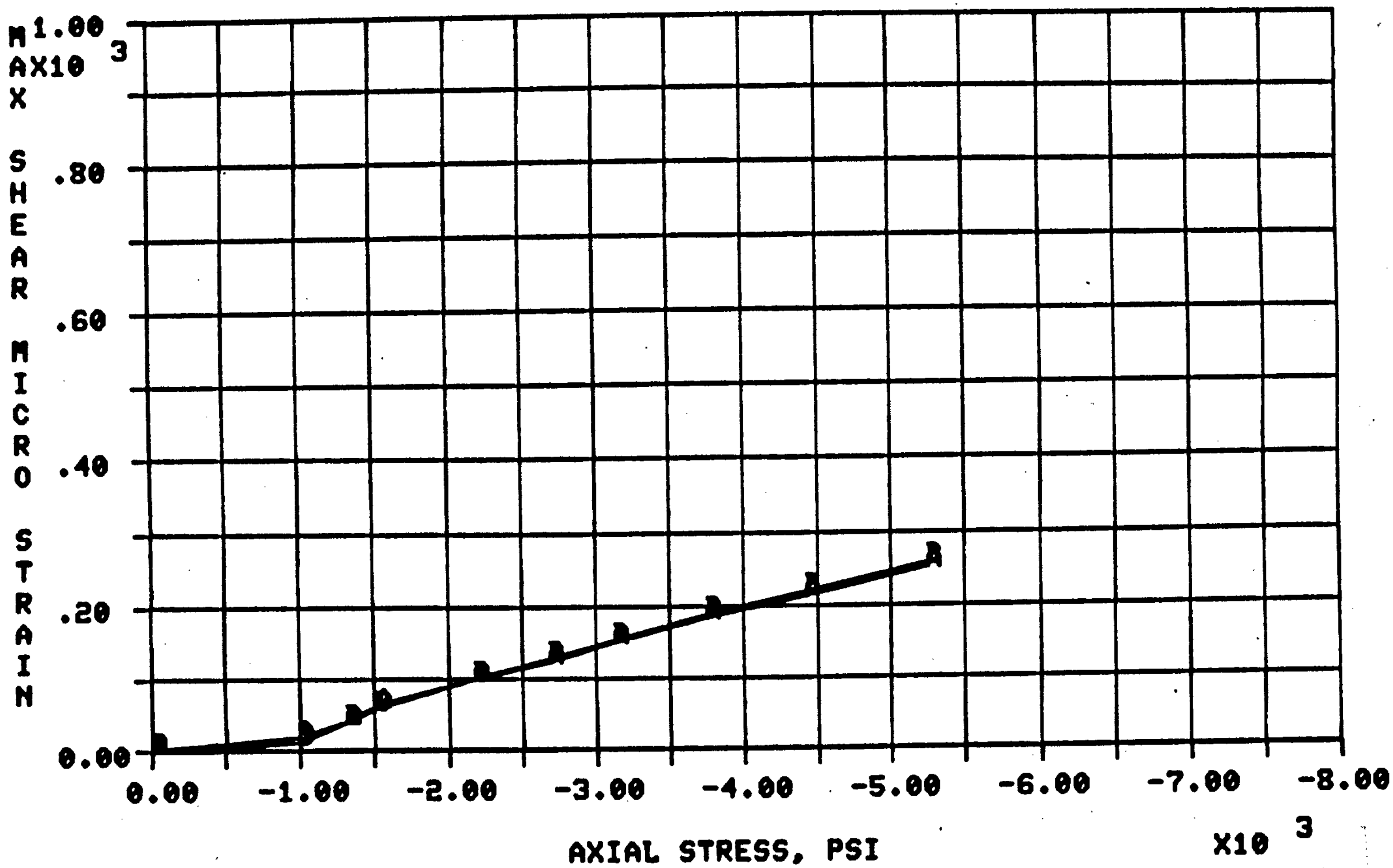


Figure 42 Test 4-A. Layup ±45° Axial Load Only
Max. Shear, Inside/Outside Rosettes

A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)

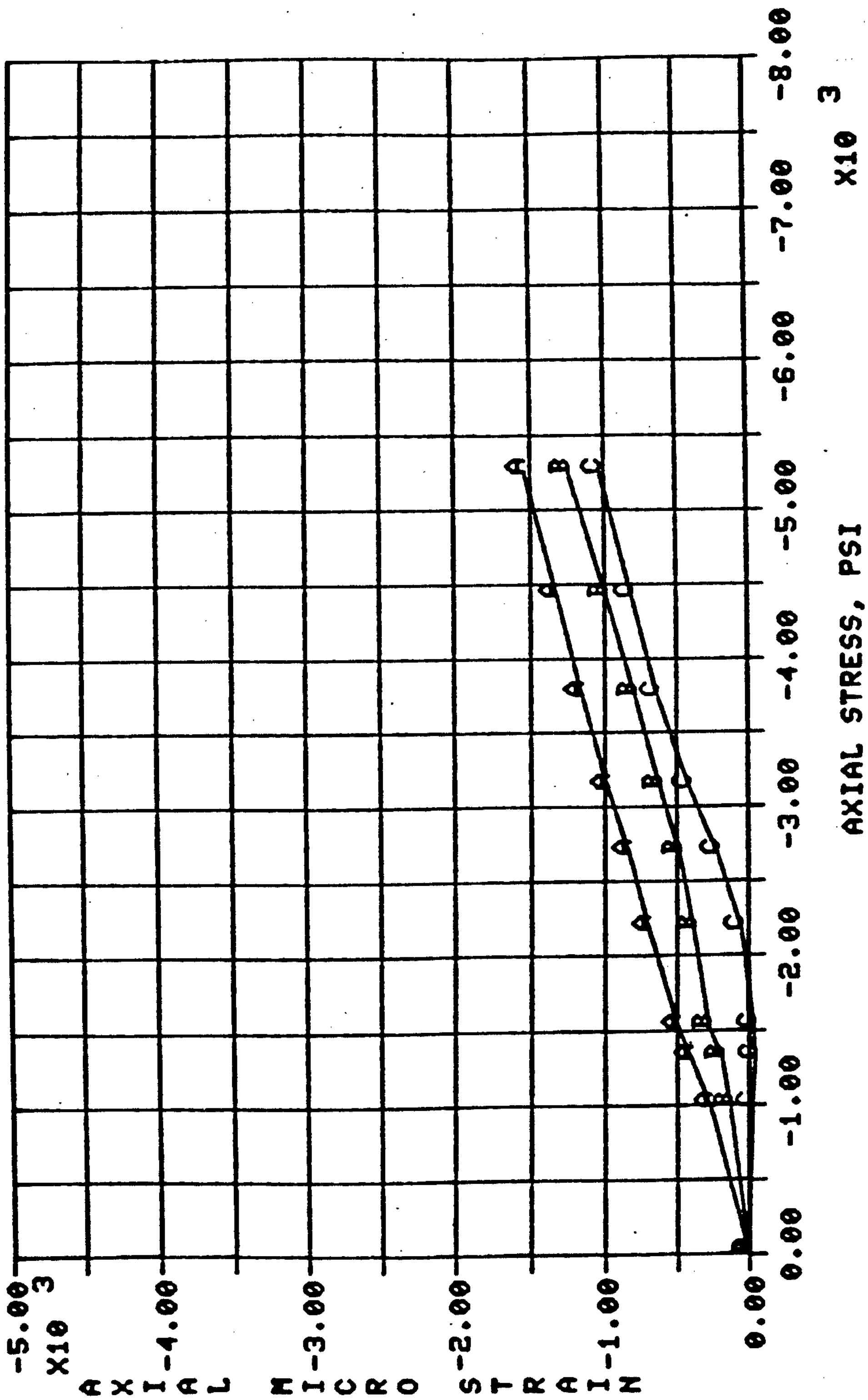


Figure 43 Test 4-A. Layup ±45° Axial Load Only
Axial Response, Edge Rosettes

A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8

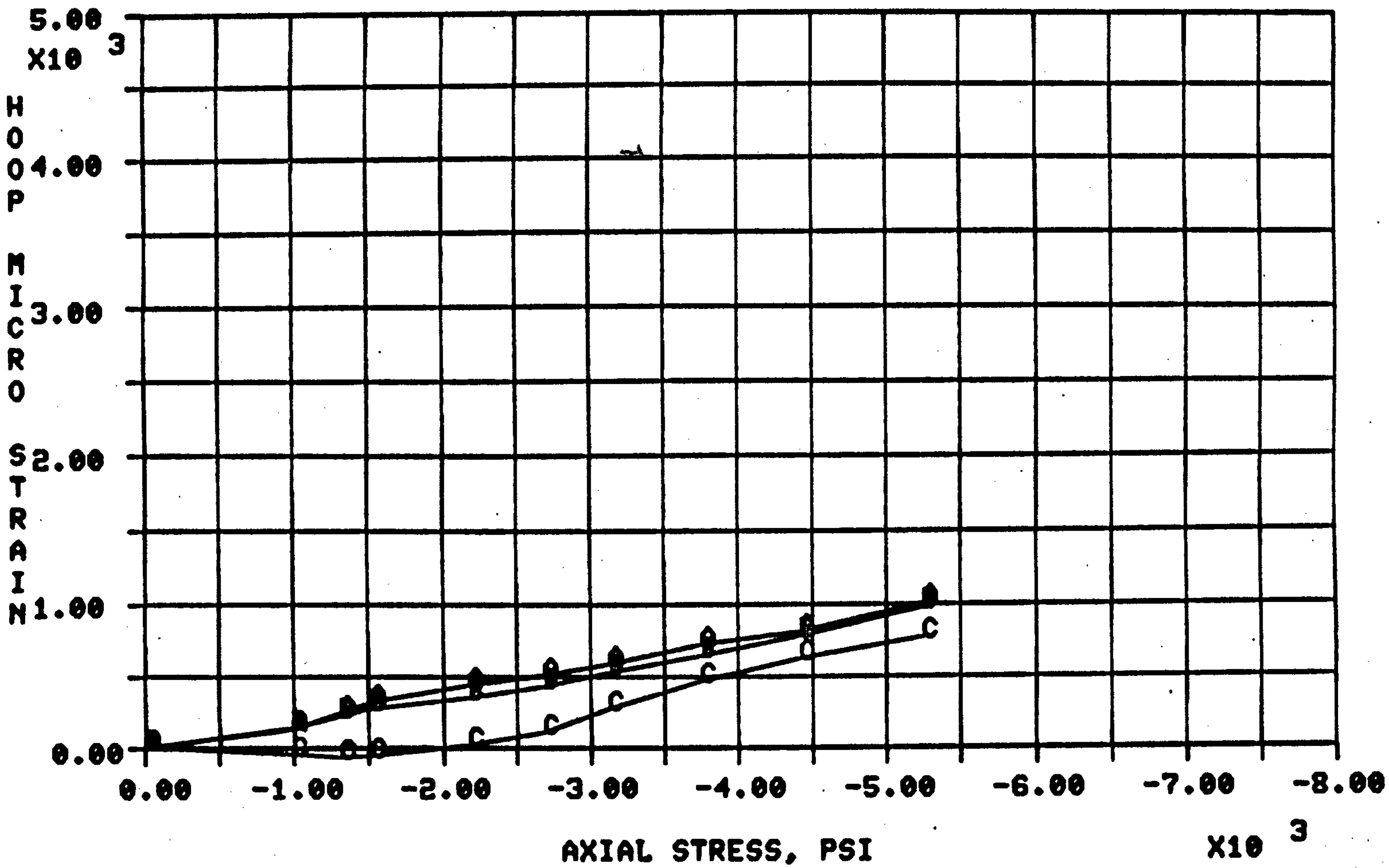


Figure 44 Test 4-A. Layup ±45° Axial Load Only
Hoop Response, Edge Rosettes

A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8

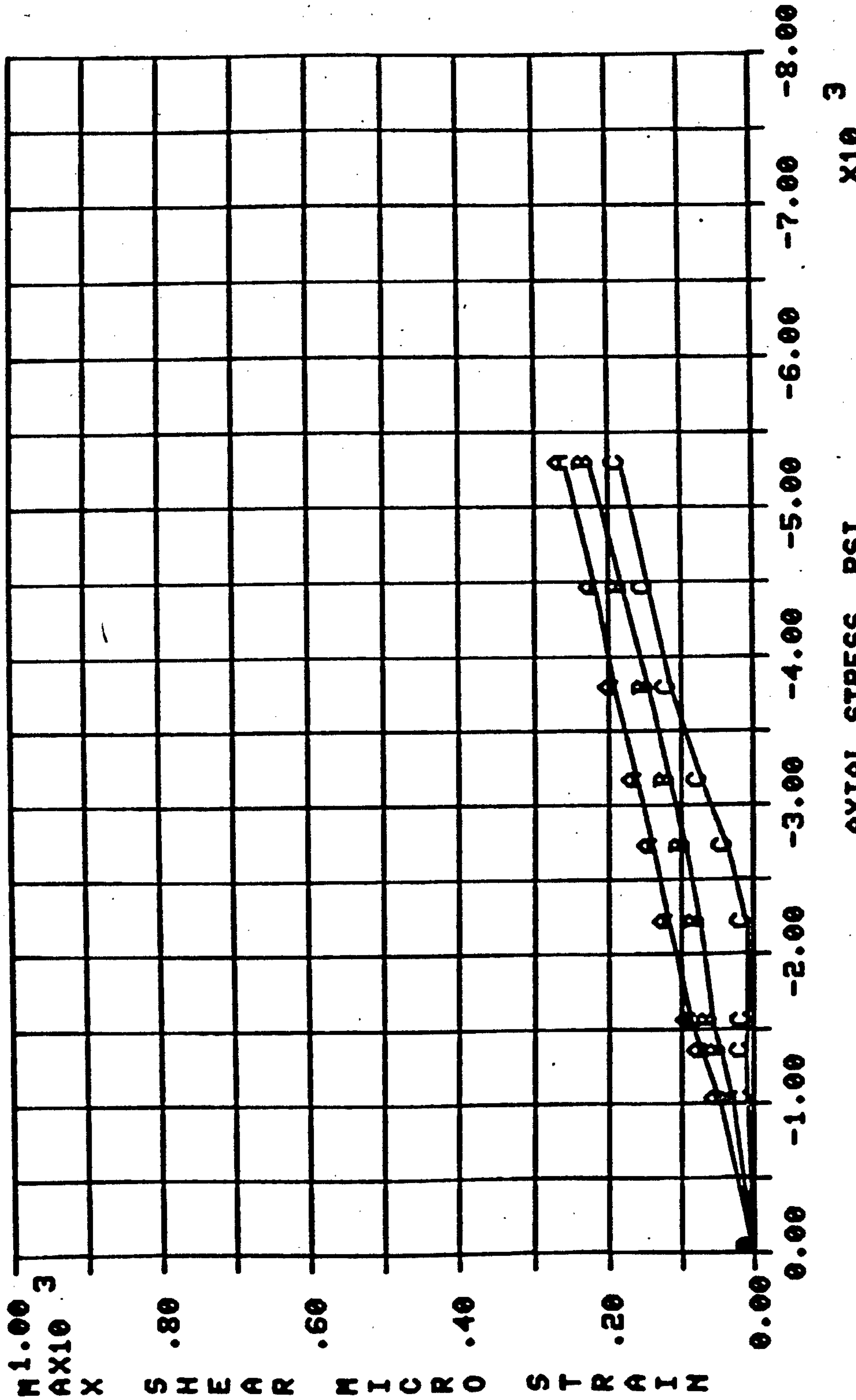


Figure 45 Test 4-A. Layup ±45° Axial Load Only
Max. Shear, Edge Rosettes

A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8

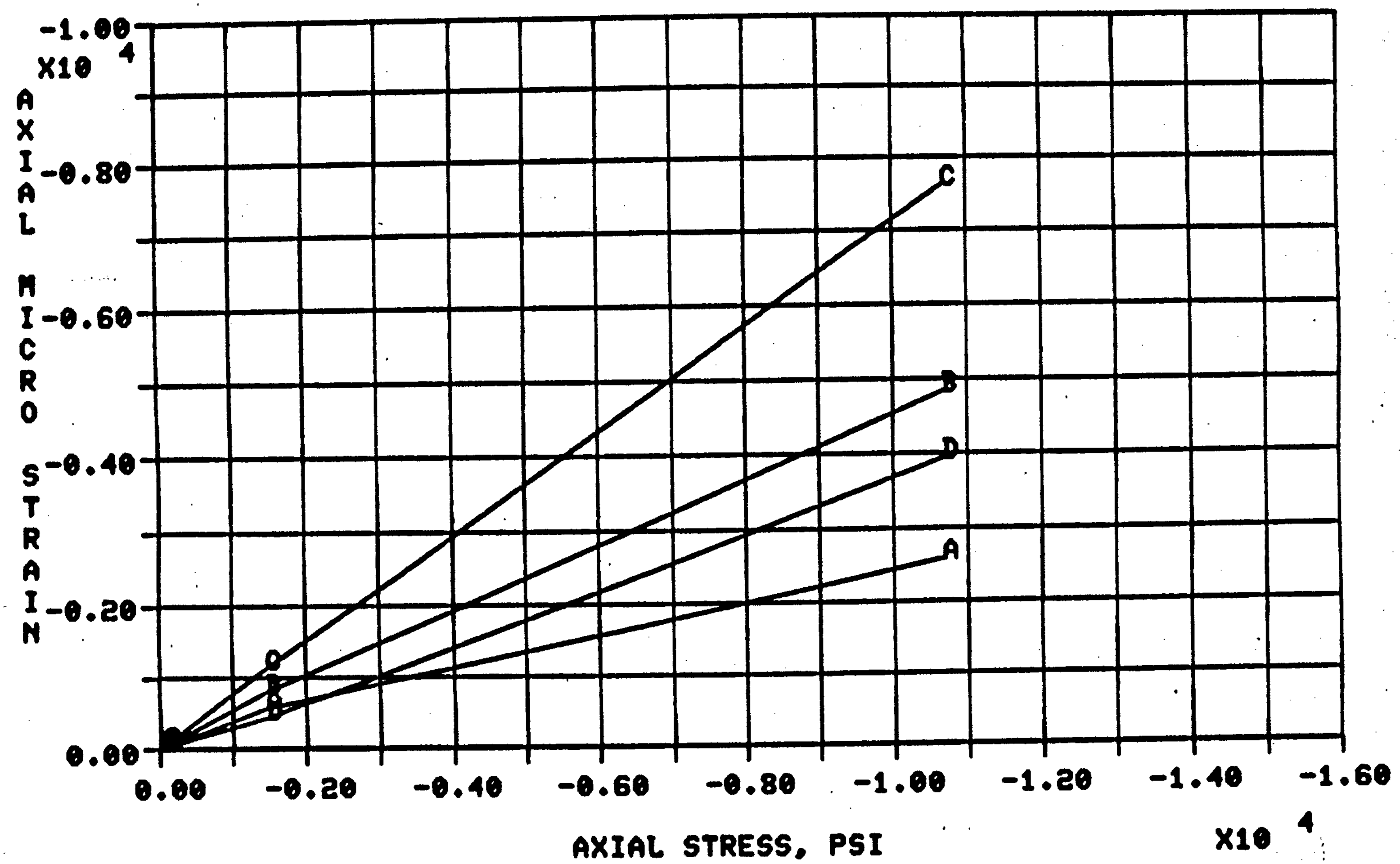


Figure 46 Test 4-B. Layup ±45° Axial Load Only
Axial Response, Outside Rosettes

A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4

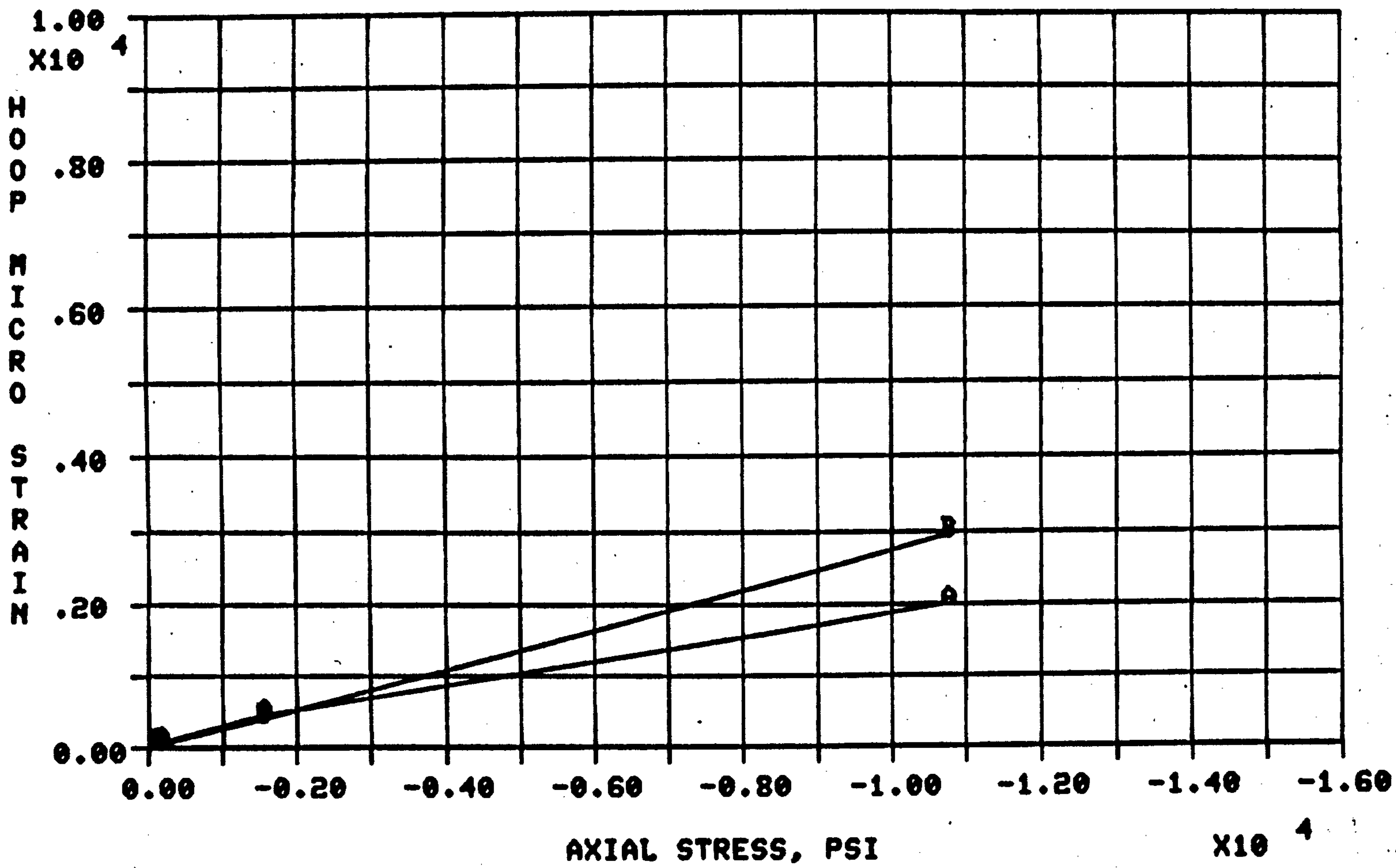


Figure 47 Test 4-B. Layup ±45° Axial Load Only
Hoop Response, Outside Rosettes

A - Rosette No. 1
B - Rosette No. 4

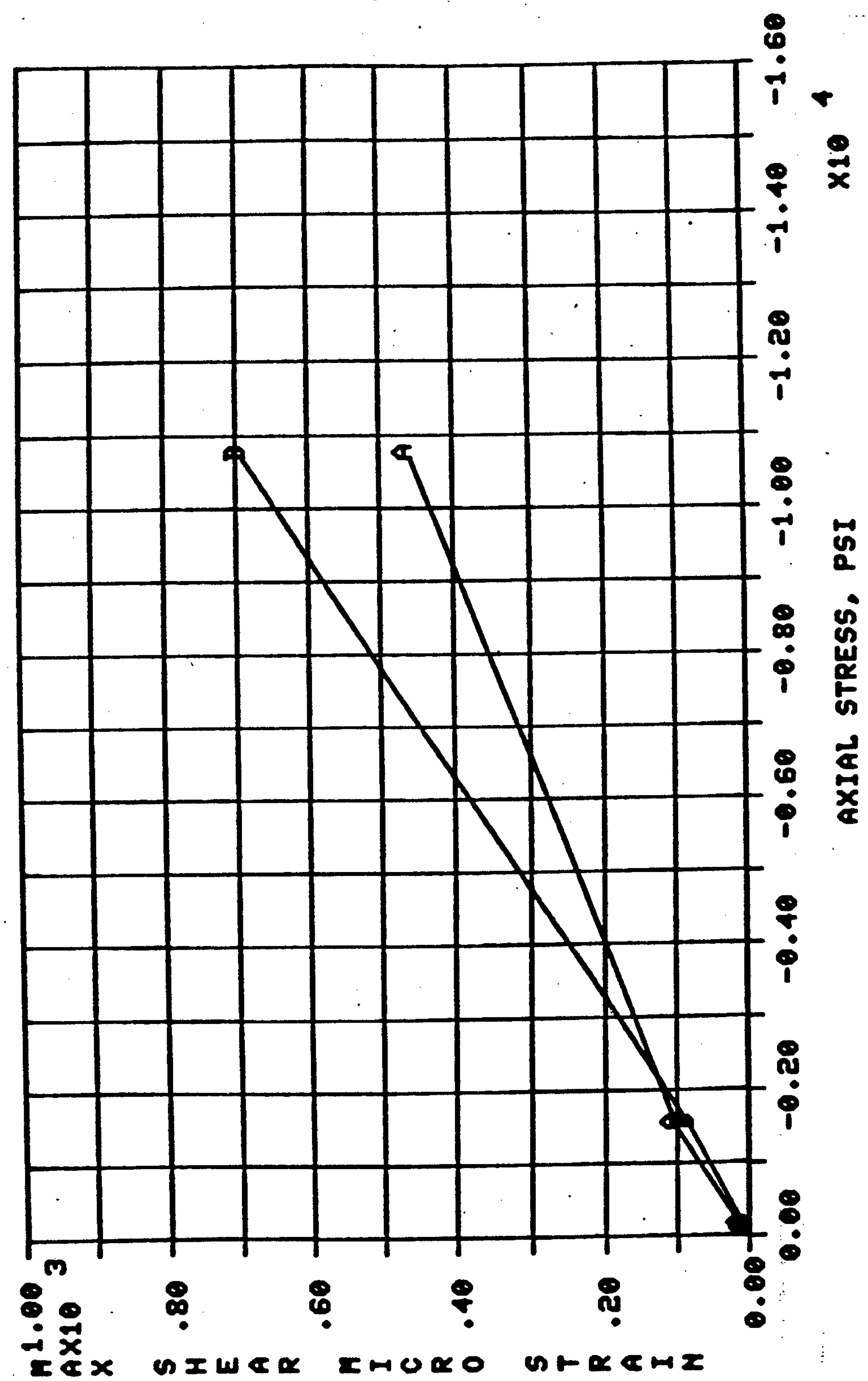


Figure 48 Test 4-B. Layup ±45° Axial Load Only
Max. Shear, Outside Rosettes

A - Rosette No. 1
B - Rosette No. 4

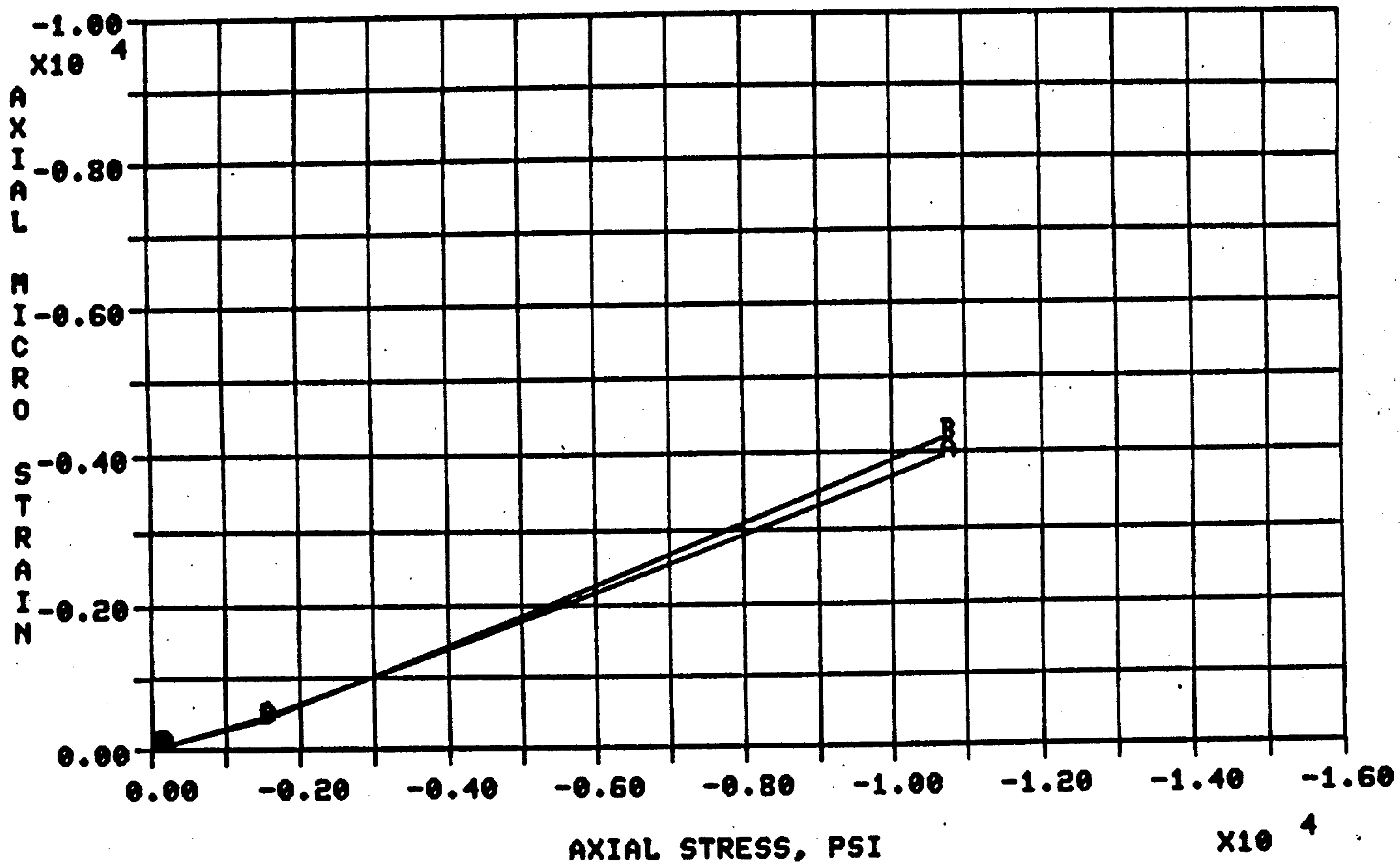


Figure 49 Test 4-B. Layup ±45° Axial Load Only
Axial Response, Inside/Outside Rosettes

A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)

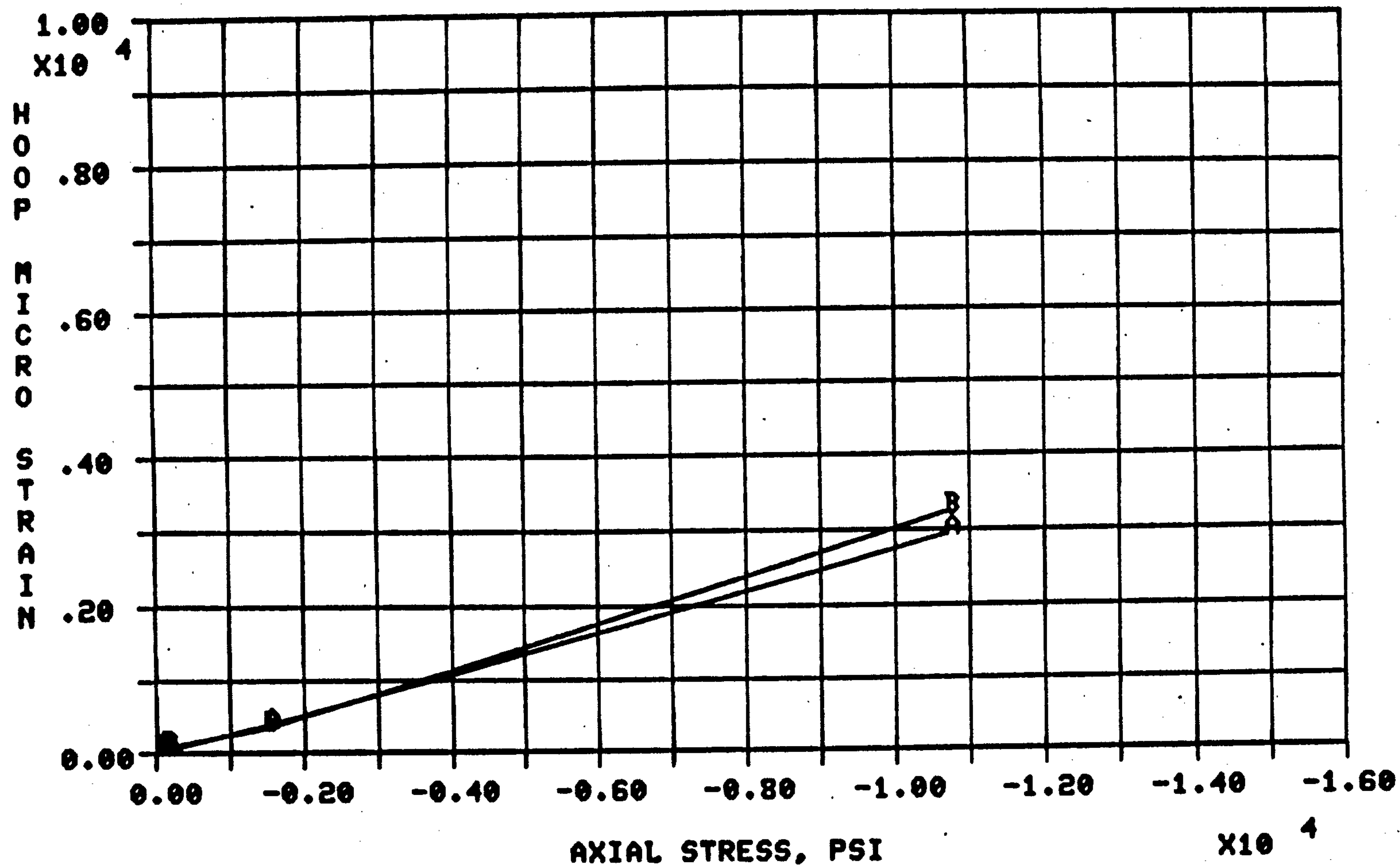


Figure 50 Test 4-B. Layup ±45° Axial Load Only
Hoop Response, Inside/Outside Rosettes

A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)

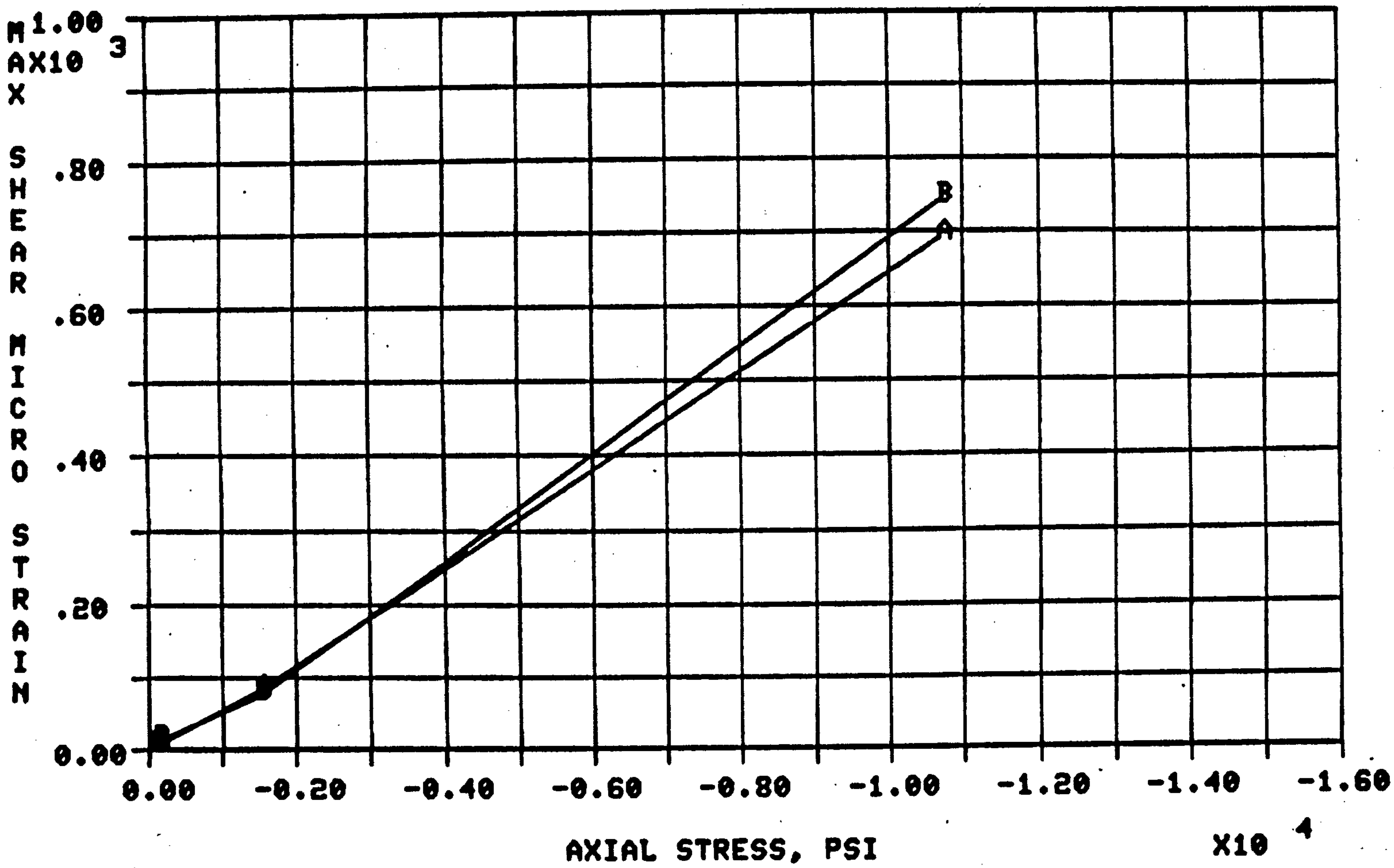


Figure 51 Test 4-B. Layup ±45° Axial Load Only
Max. Shear, Inside/Outside Rosettes

A - Rosette No. 4
B - Rosette No. 5 (inside)

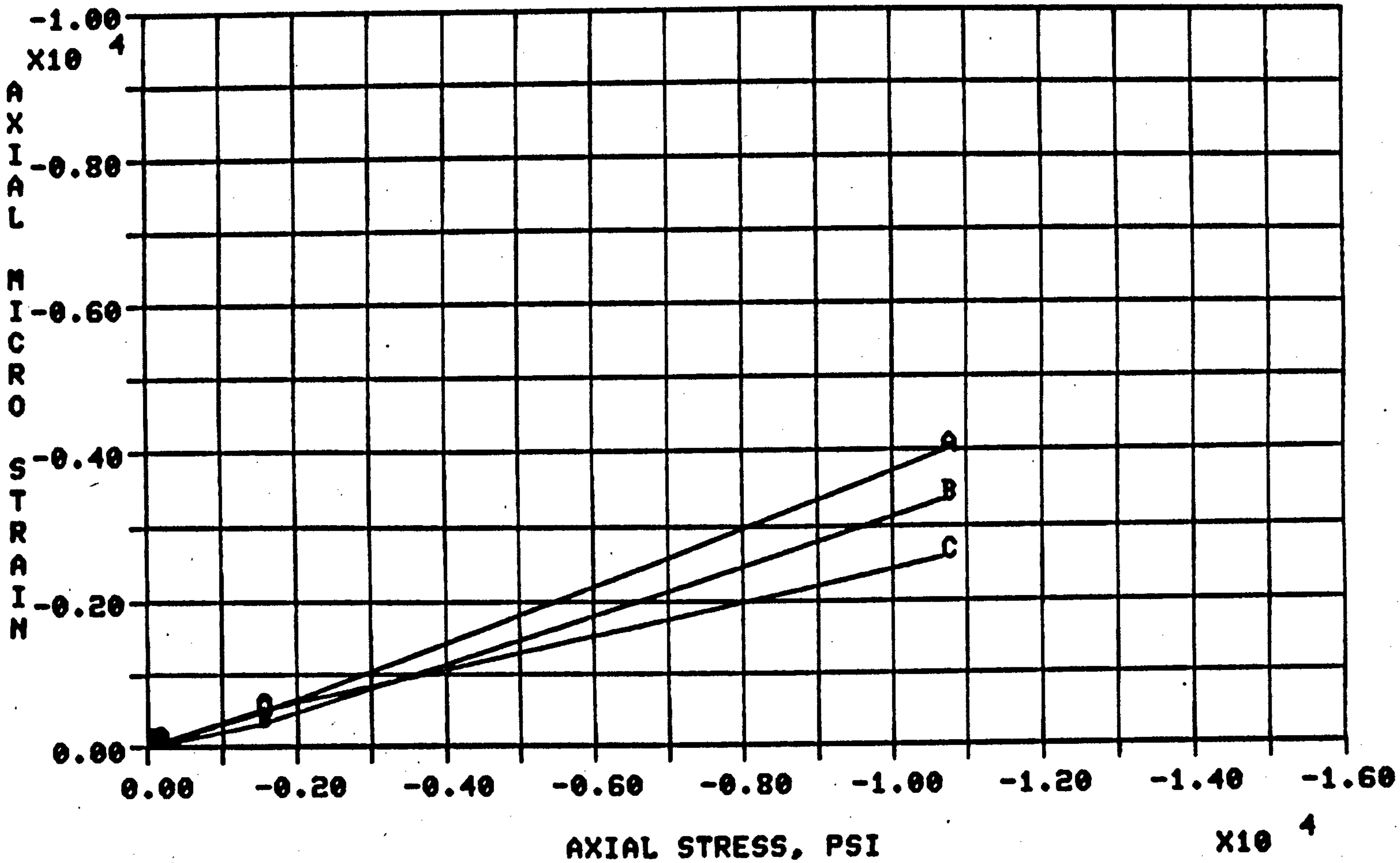


Figure 52 Test 4-B. Layup ±45° Axial Load Only
Axial Response, Edge Rosettes

A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8

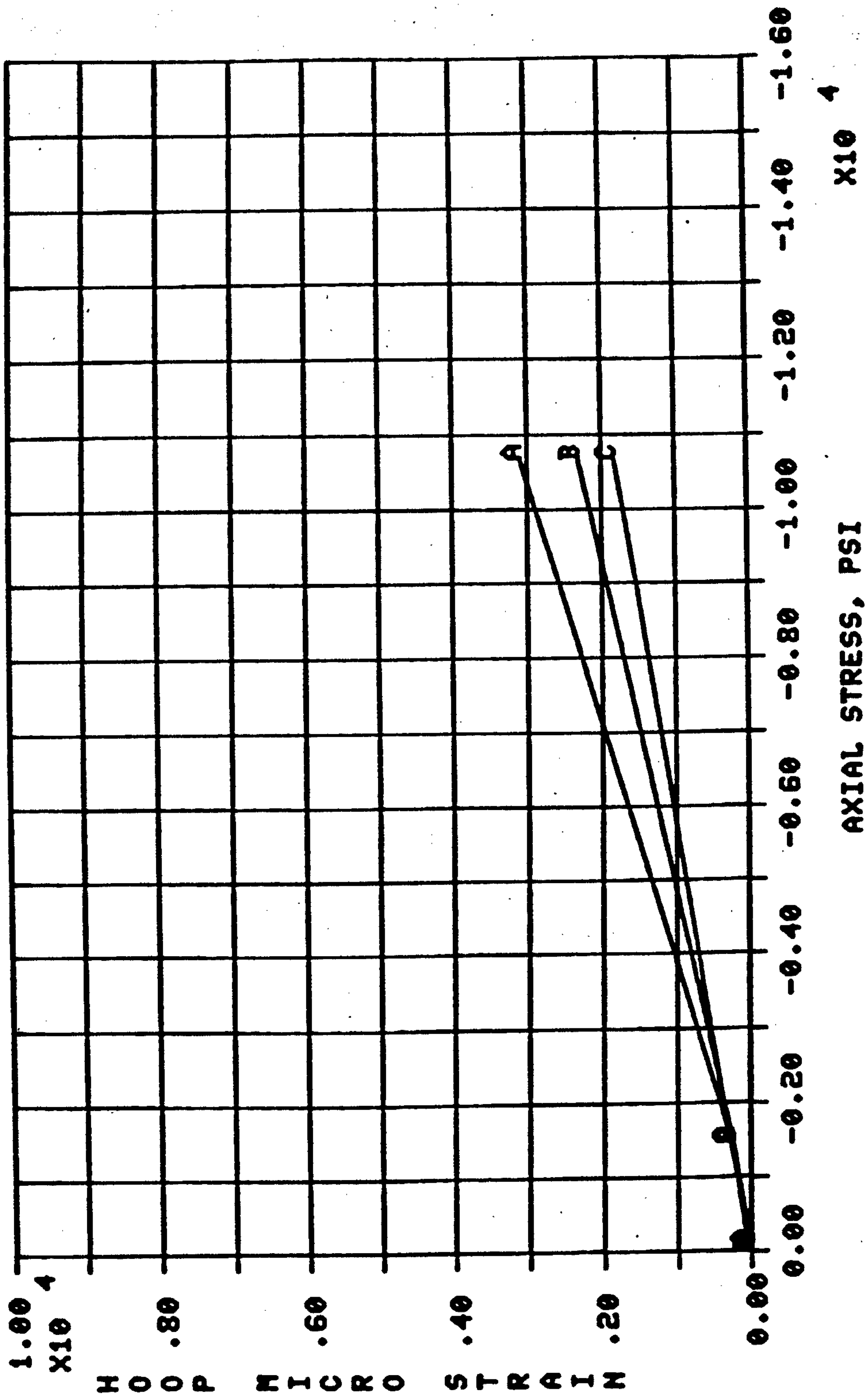


Figure 53 Test 4-B. Layup ±45° Axial Load Only
Hoop Response, Edge Rosettes

A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8

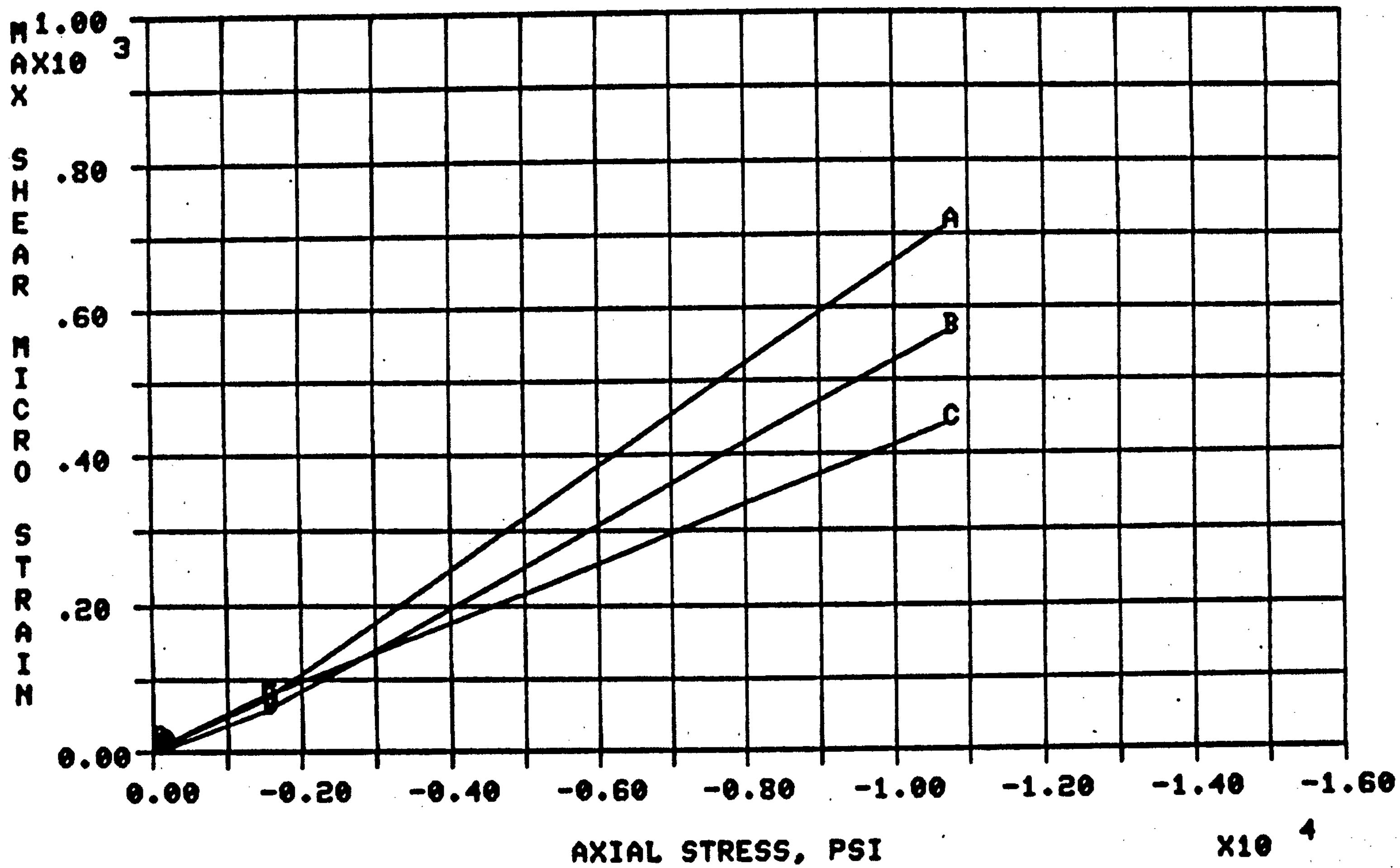


Figure 54 Test 4-B. Layup ±45° Axial Load Only
Max. Shear, Edge Rosettes

A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8

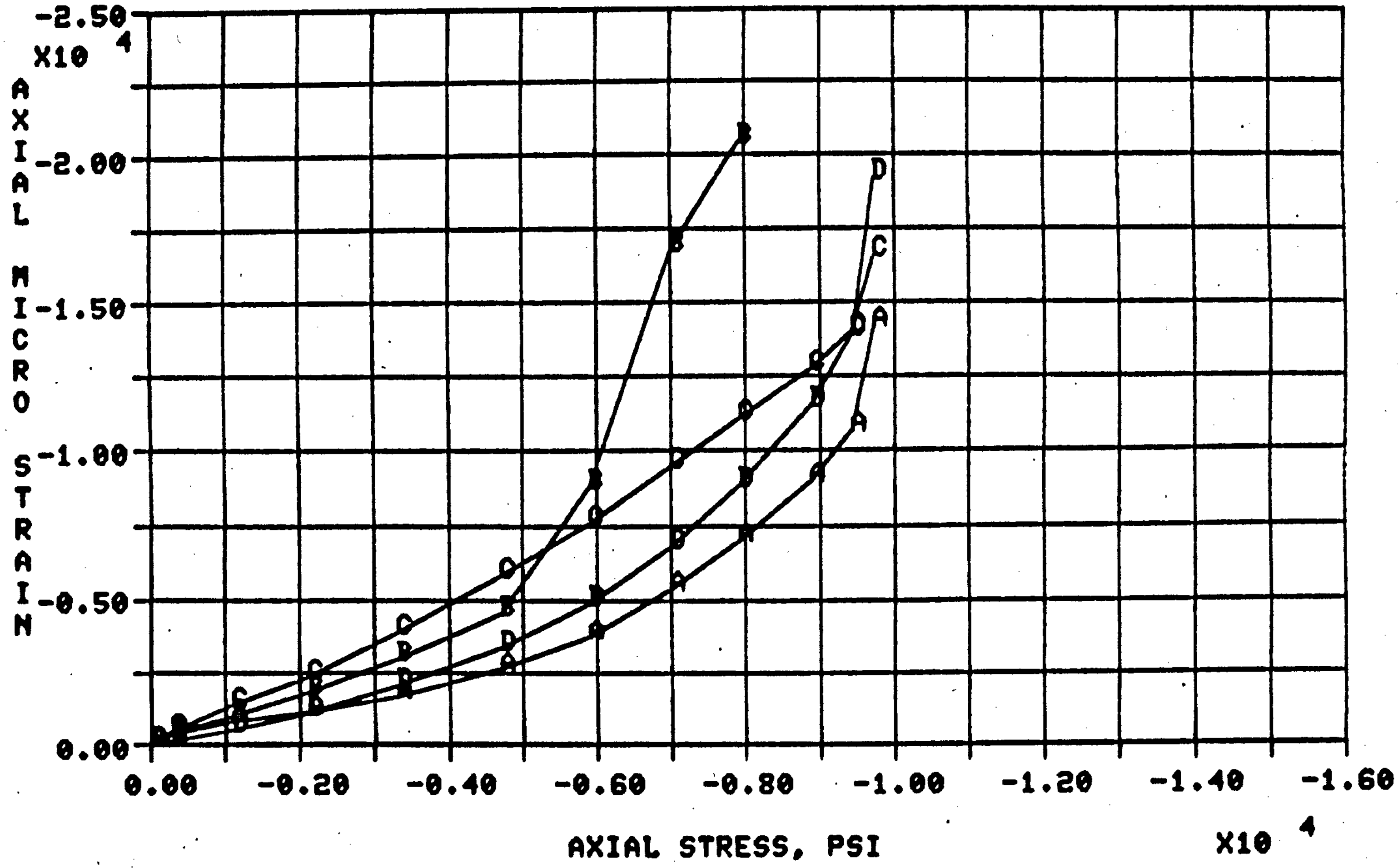


Figure 55 Test 4-C. Layup ±45° Axial Load Only
Axial Response, Outside Rosettes

A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4

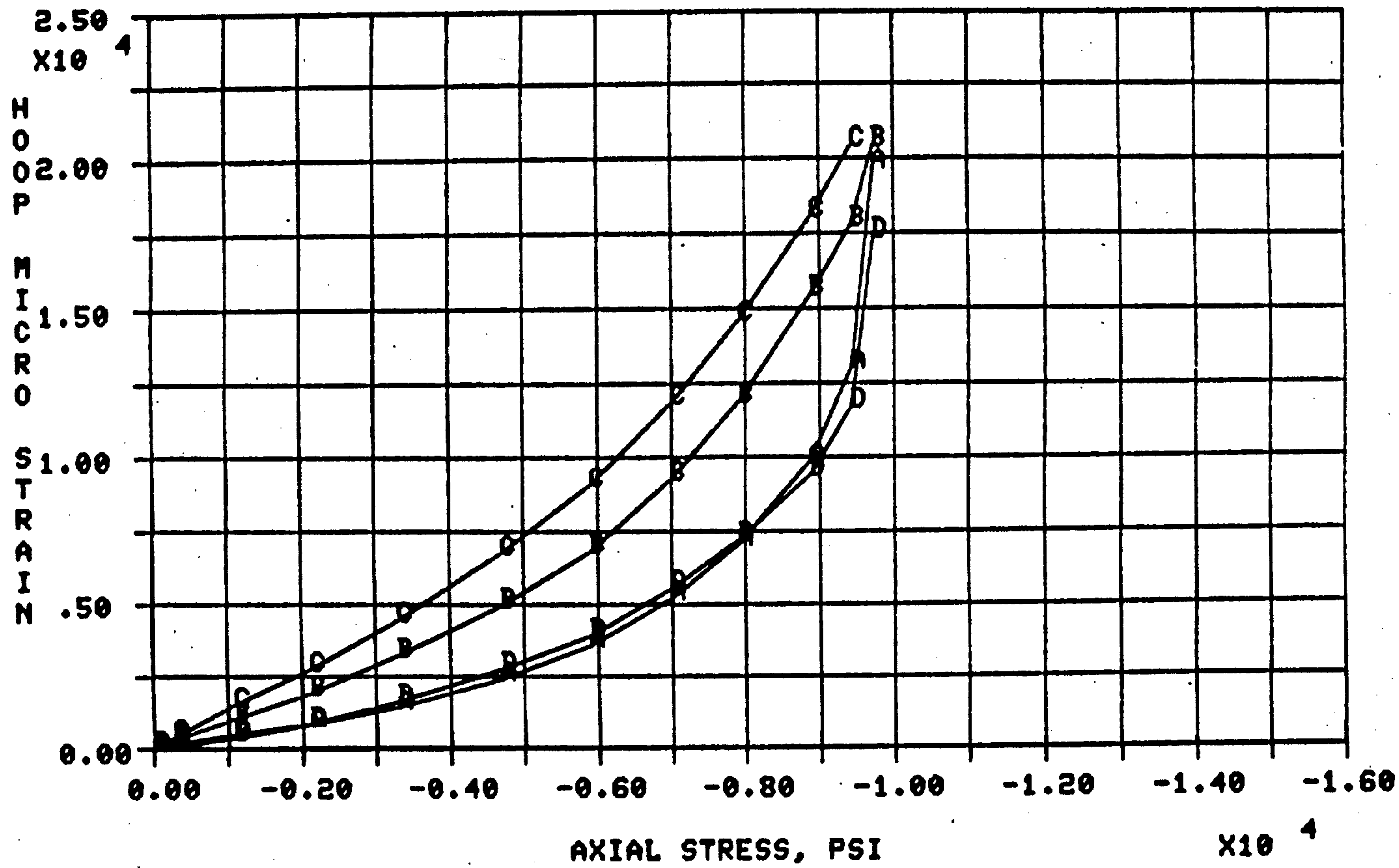


Figure 56 Test 4-C. Layup ±45° Axial Load Only
Hoop Response, Outside Rosettes

A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4

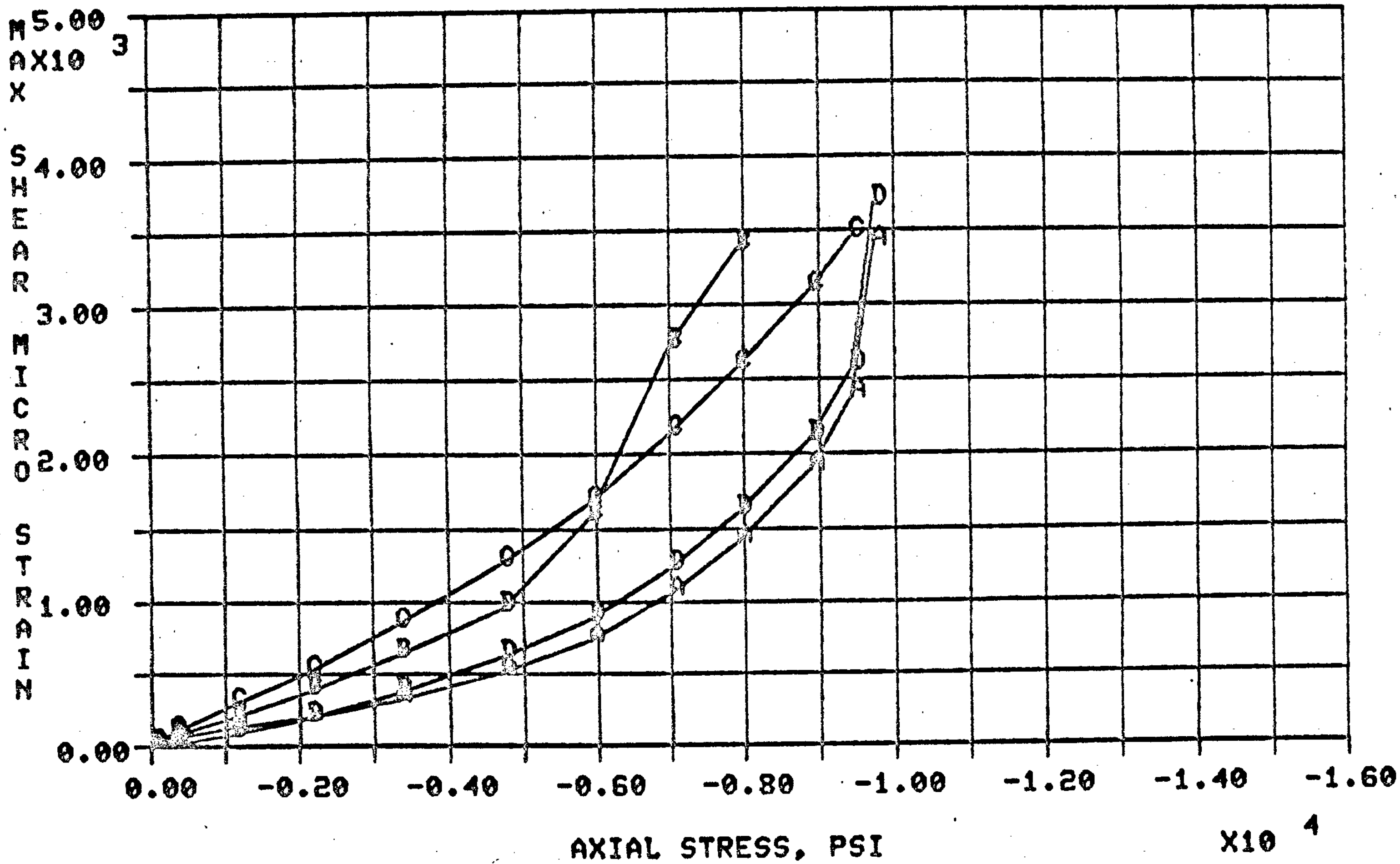


Figure 57 Test 4-C. Layup ±45 Axial Load Only
Max. Shear Response, Outside Rosettes

A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4

surface of the specimen for Test 4-C. Strains at Locations 1 and 4 are in good agreement . Figures 58, 59 and 60 are comparison plots of axial, hoop and maximum shear strains, respectively, versus axial stress for the inside/outside comparison gages. Here good agreement is shown, indicating very little bending is occurring. Figures 61, 62 and 63 are comparison plots of axial, hoop and maximum shear strains, respectively, versus axial stress for the edge rosettes. Fairly good agreement is shown, much better than the gages located at the center of the specimen showed.

If the results of Tests 4-A, 4-B and 4-C are plotted together, such as in Figures 64 through 67, an interesting point comes to light. From these figures, one sees that Test 4-A and Test 4-B give almost identical results, while Test 4-C produced much higher strains. Also, note that the axial stress of Test 4-B is higher than that of Test 4-C. It is thought that Test 4-B damaged the specimen (internal breakage of fibers), and this could account for the behavior of Test 4-C.

For Test 5, external pressure was applied to the same specimen as used in Tests 4-A, 4-B and 4-C. Figures 68, 69 and 70 present the axial, hoop and maximum shear strains, respectively, for two rosettes located on the inside surface, one at the center and one at the edge. Both rosettes are located at the same angular location. The results are in very poor agreement. This could be because the specimen was damaged in Test 4, as discussed above, or because buckling was taking place. Fracture of the specimen, shown in Figure 71, was from ply delamination and hoop direction blooming.

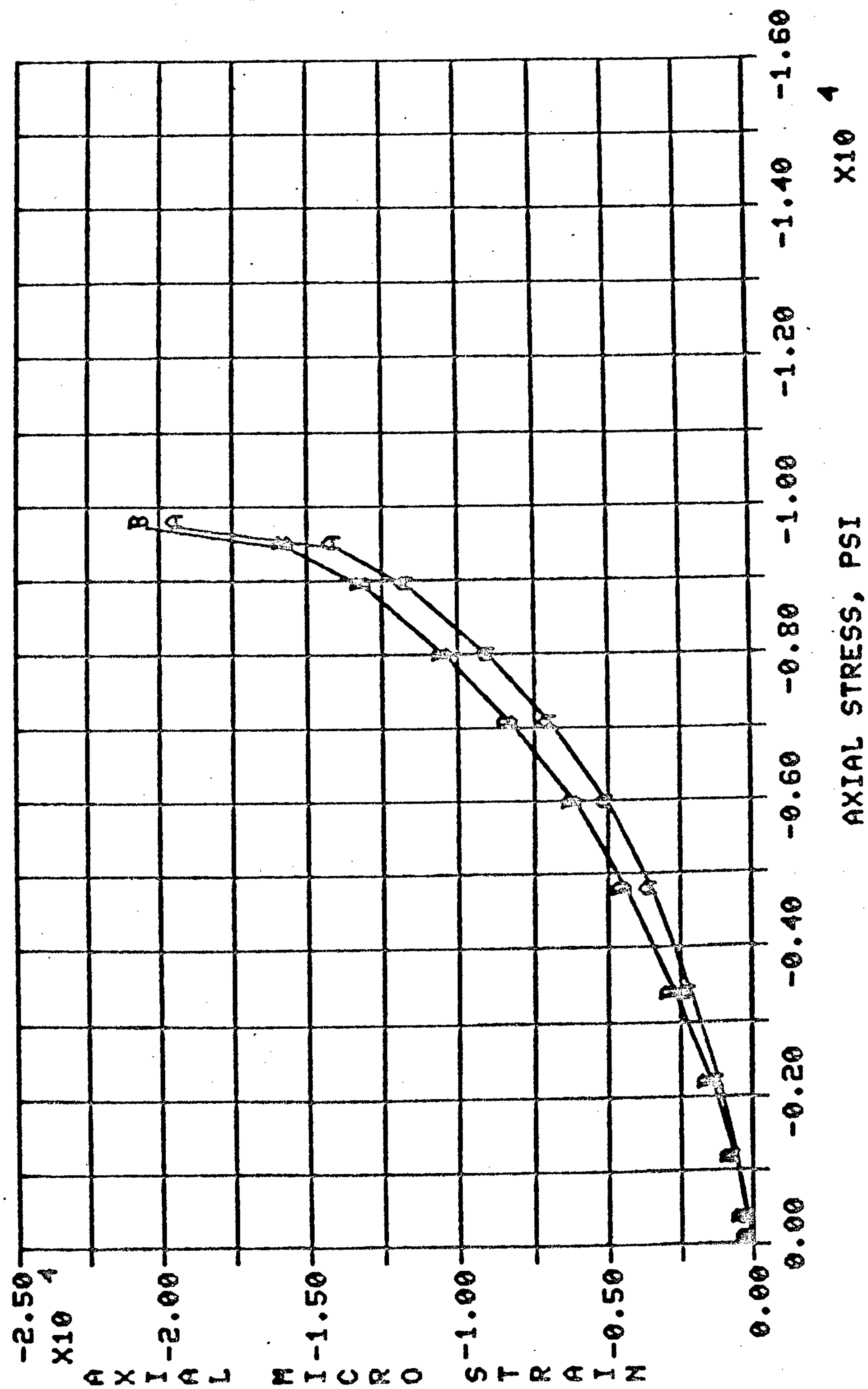


Figure 58 Test 4-C Layup ±45° Axial Load Only
Axial Response, Inside/Outside Rosettes

A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)

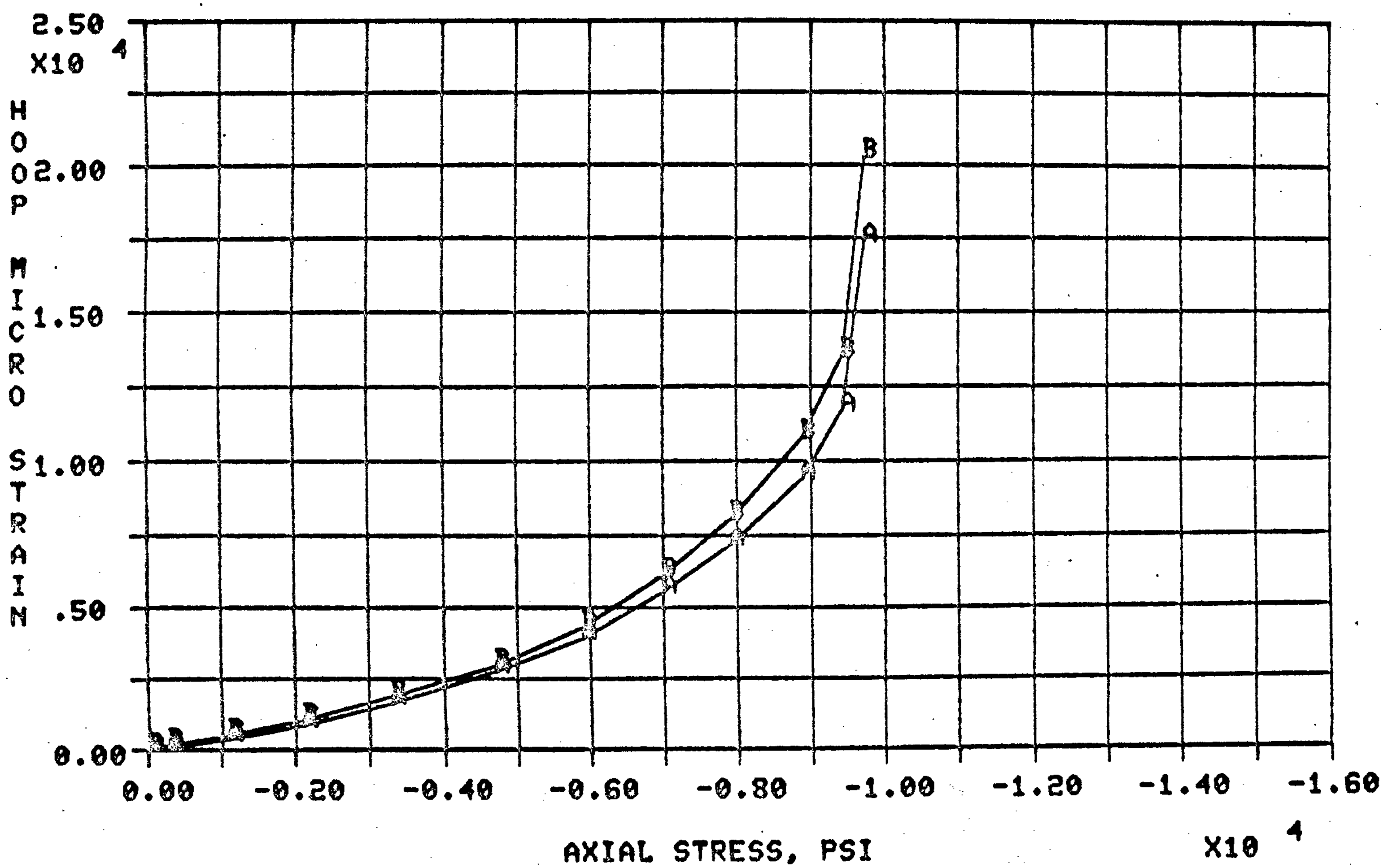


Figure 59 Test 4-C. Layup ±45° Axial Load Only
Hoop Response, Inside/Outside Rosettes

A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)

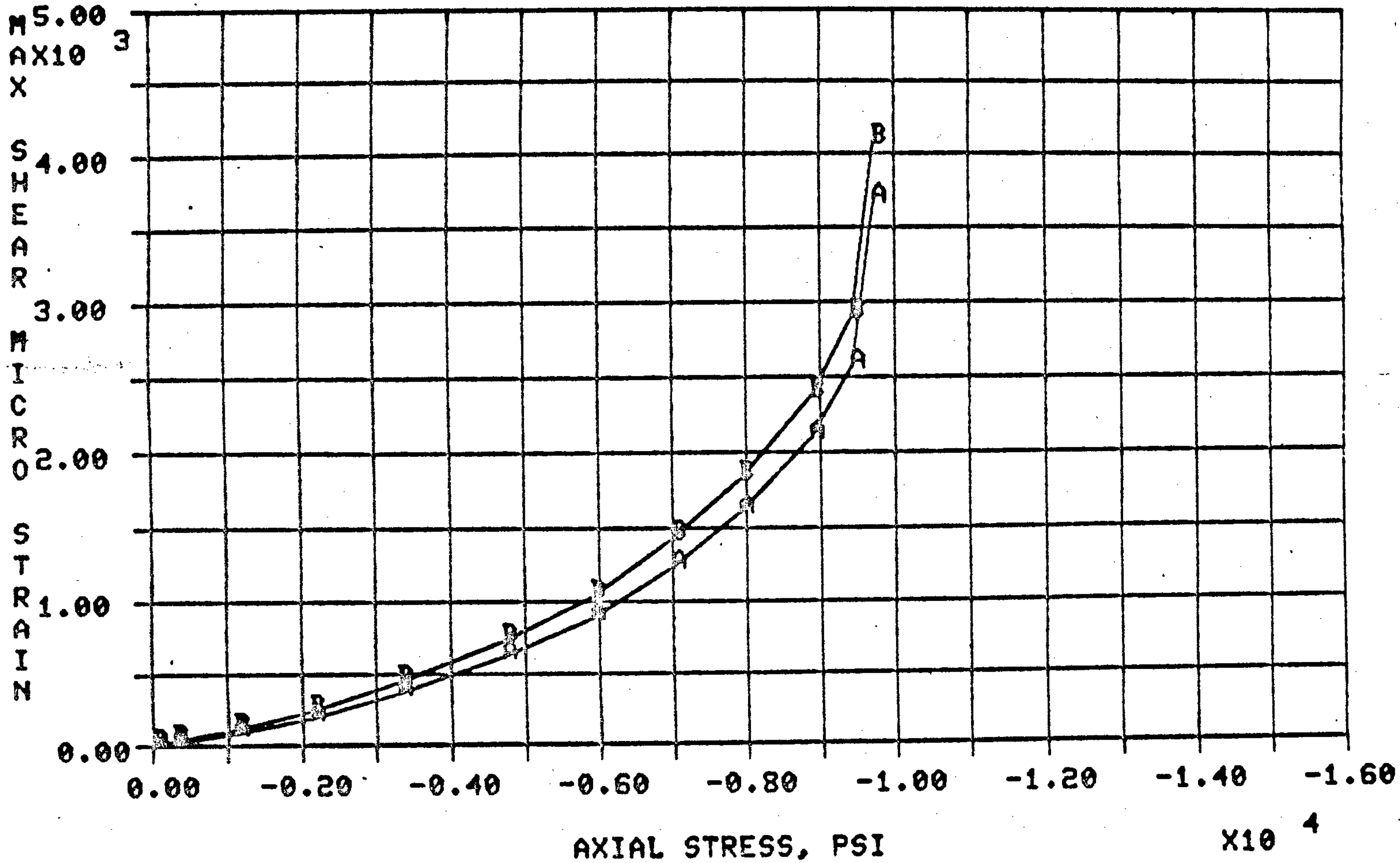


Figure 60 Test 4-C. Layup ±45° Axial Load Only
Max. Shear, Inside/Outside Rosettes

A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)

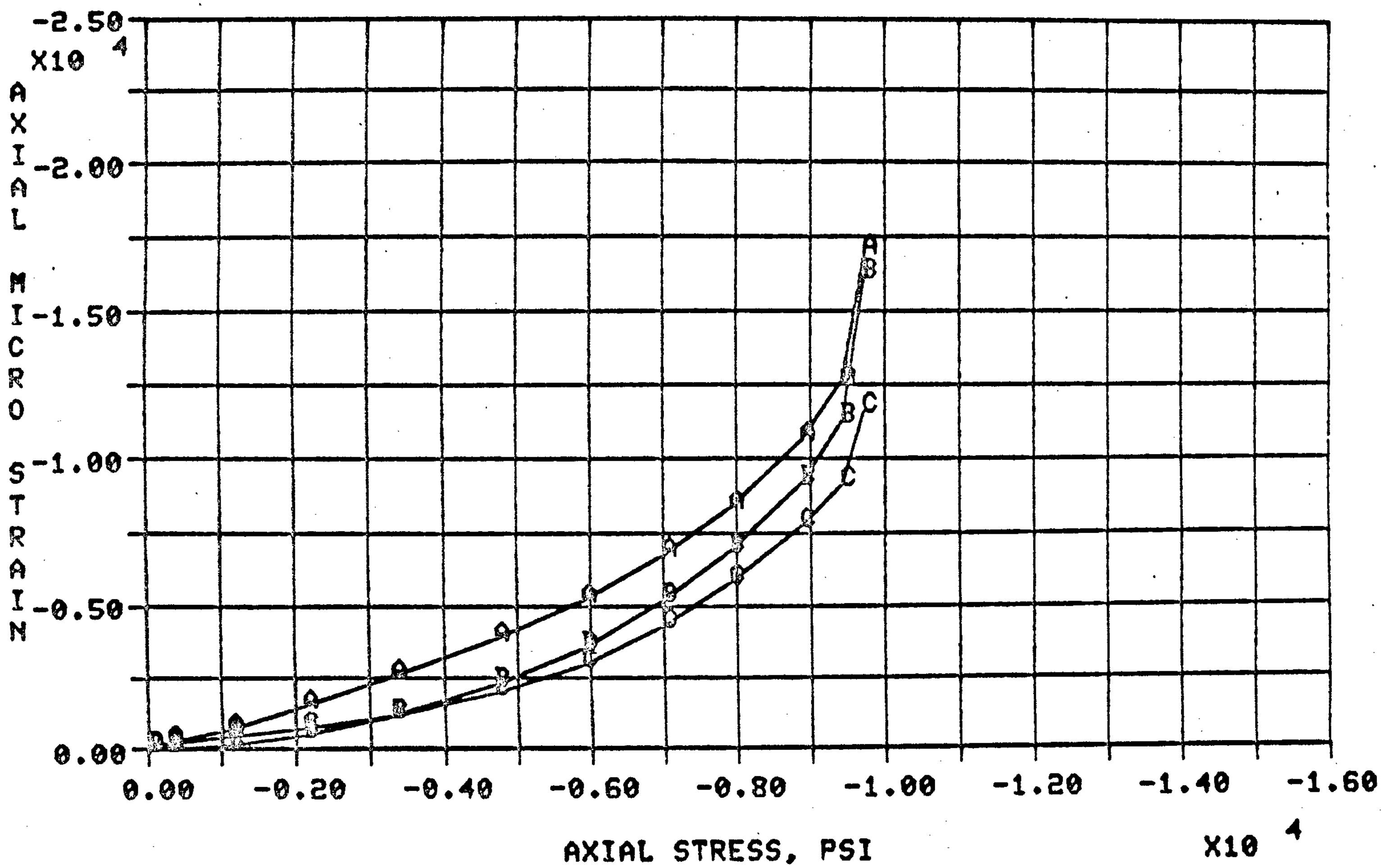


Figure 61 Test 4-C. Layup ±45° Axial Load Only
Axial Response, Edge Rosettes

A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8

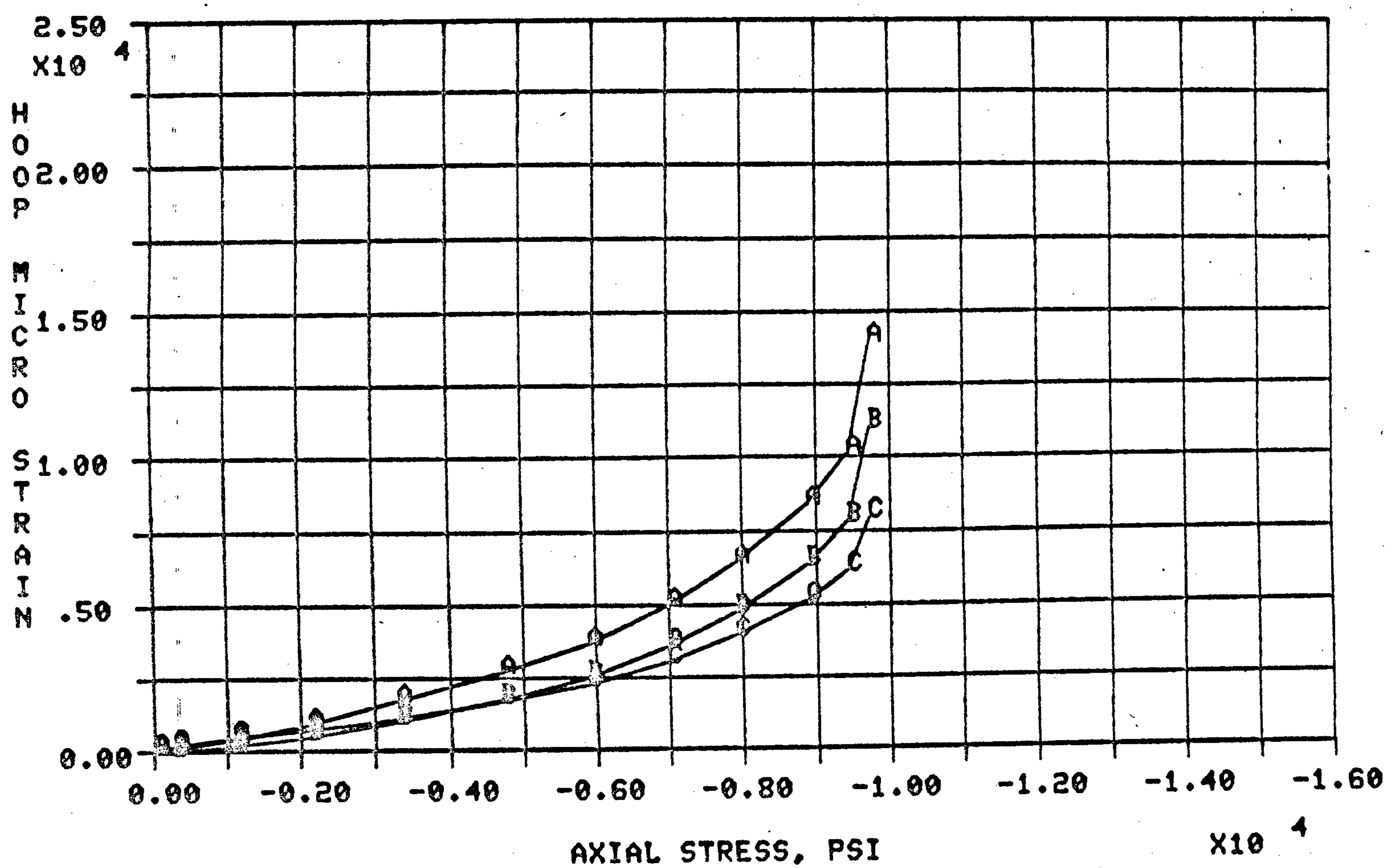


Figure 62 Test 4-C. Layup ±45° Axial Load Only
Hoop Response, Edge Rosettes

A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8

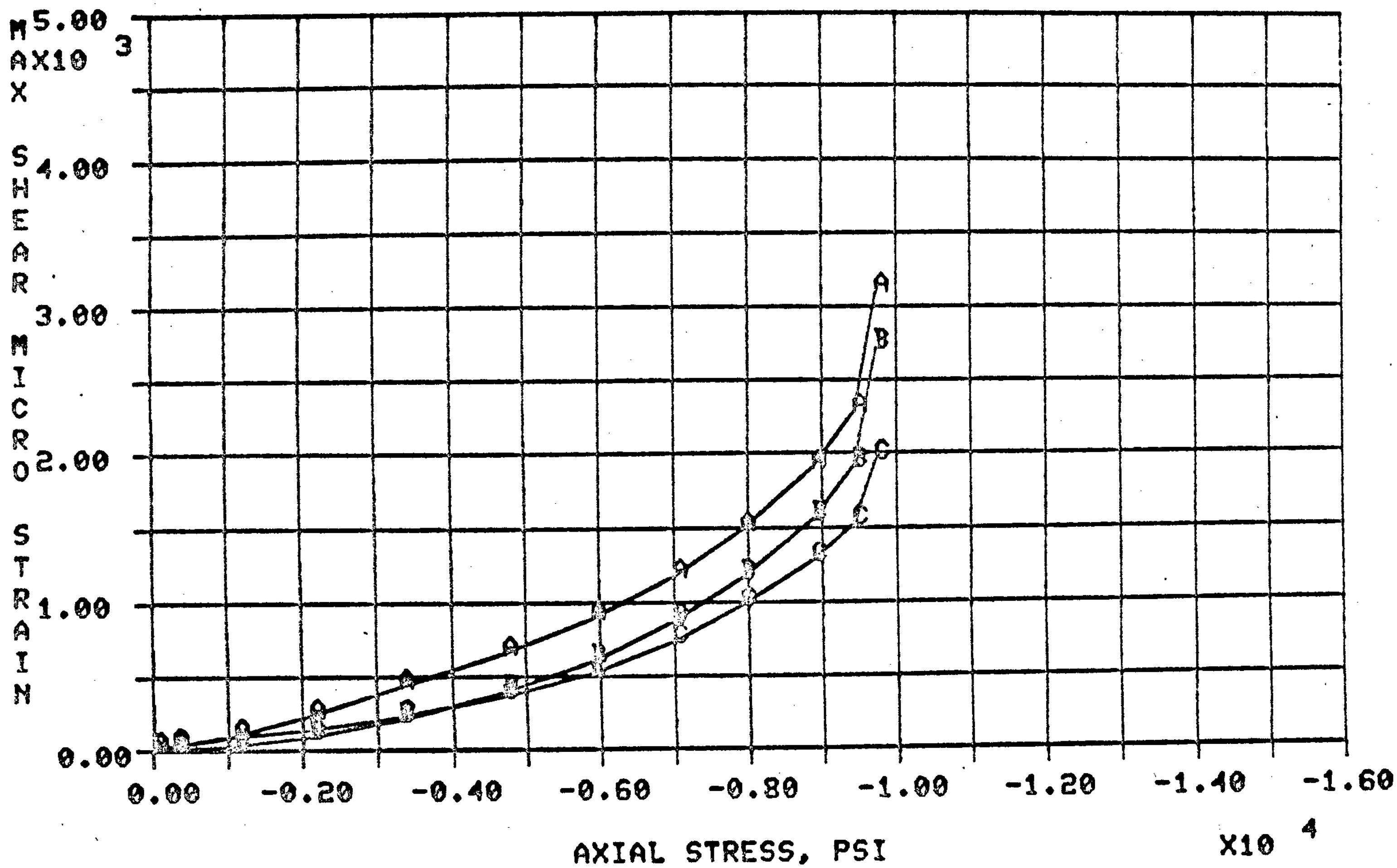


Figure 63 Test 4-C. Layup ±45° Axial Load Only
Max. Shear, Edge Rosettes

A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8

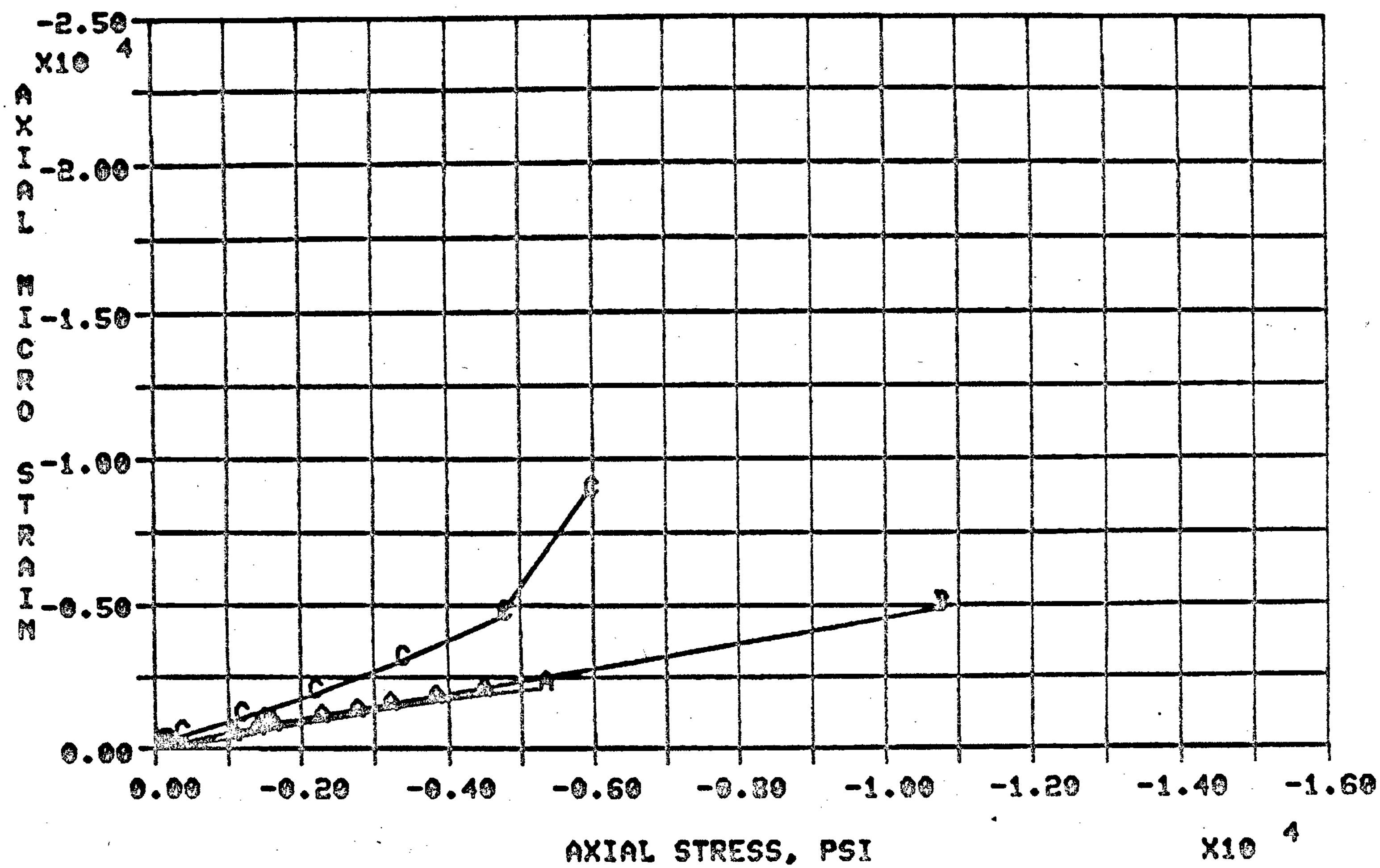


Figure 64 Tests 4-A, B, C. Layup ±45° Axial Only
Axial Response, Rosette No. 2

A - Test 4-A
B - Test 4-B
C - Test 4-C

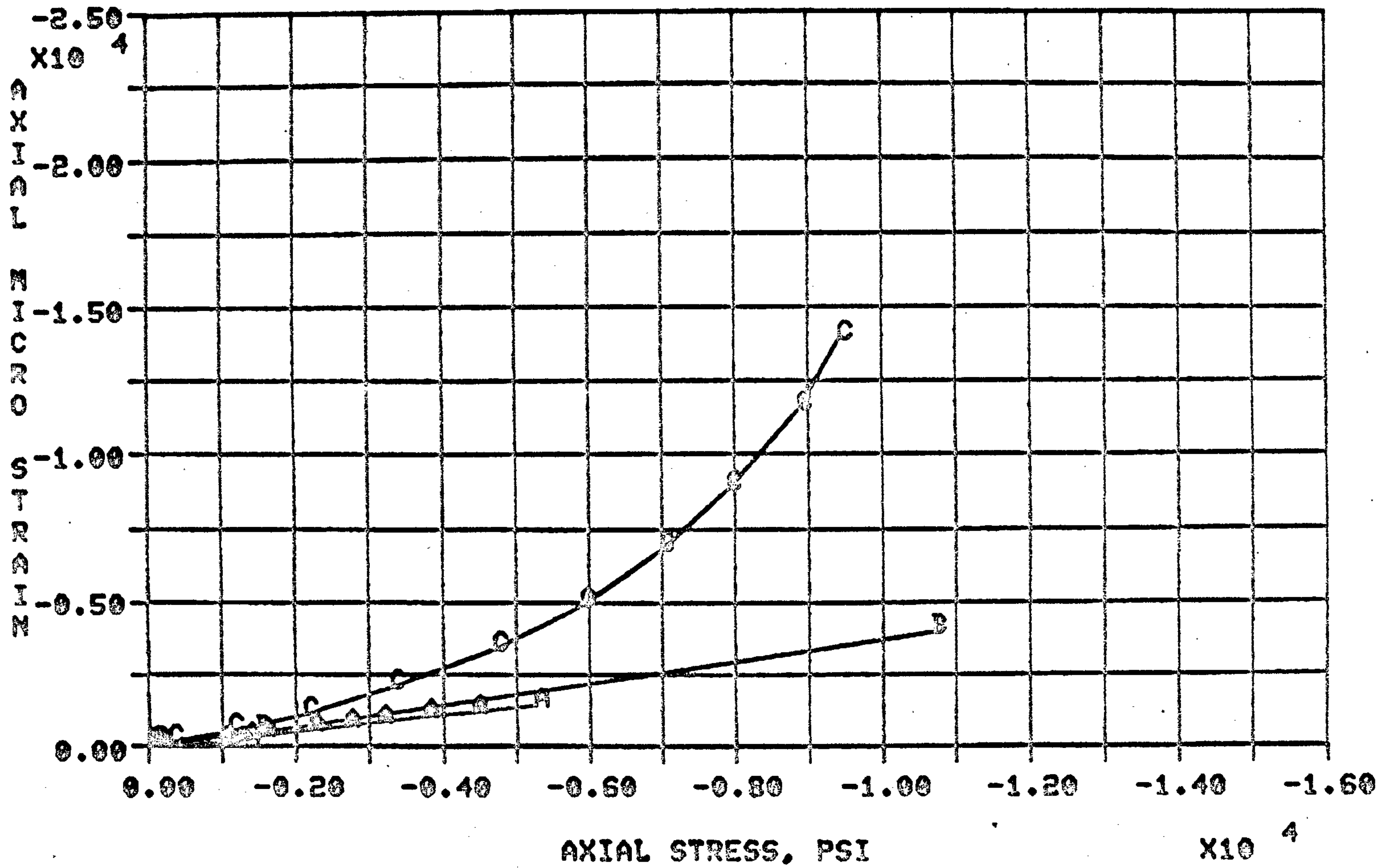


Figure 65 Tests 4-A, B, C. Layup ±45° Axial Only
Axial Response, Rosette No. 4

A - Test 4-A
B - Test 4-B
C - Test 4-C

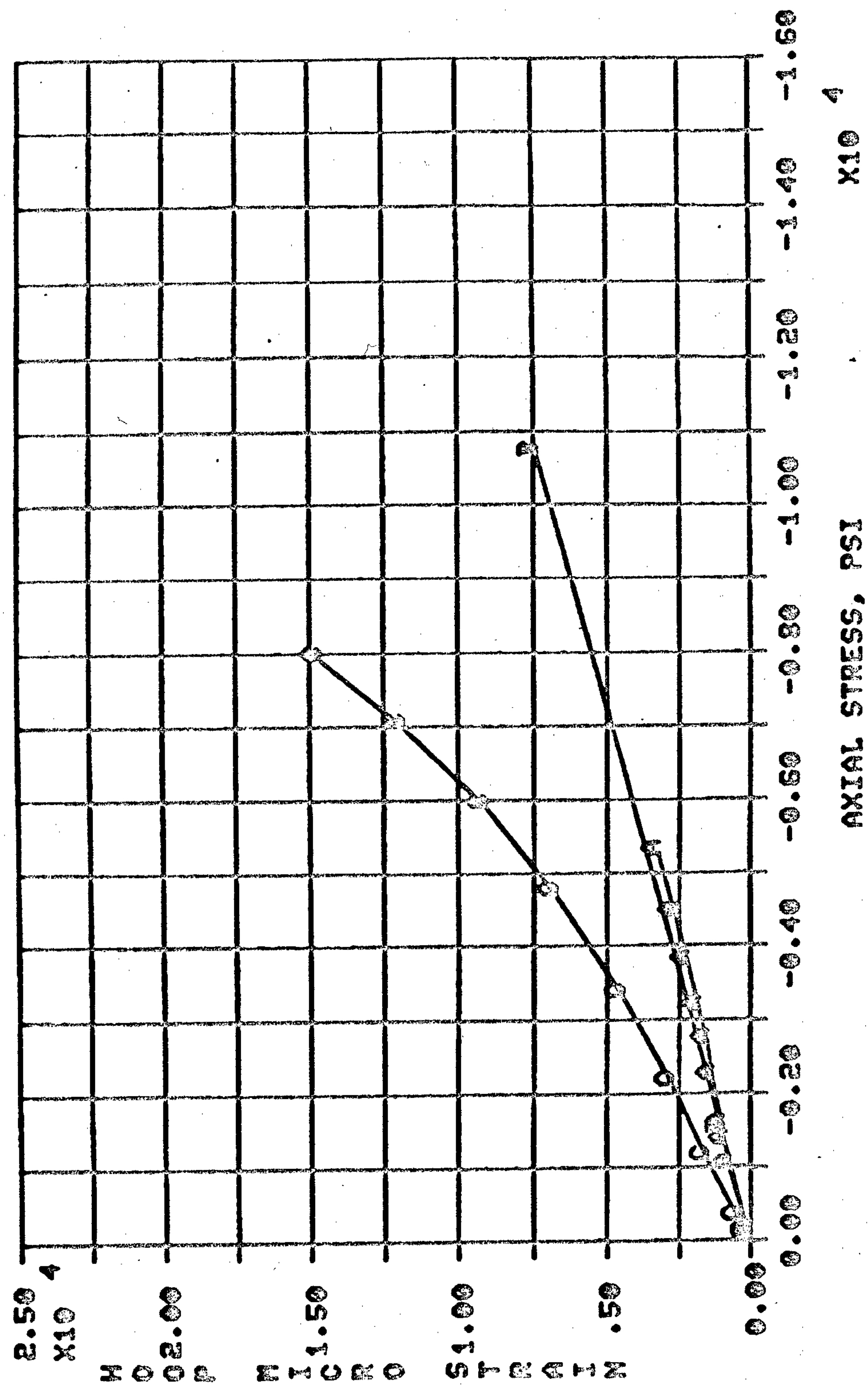


Figure 66 Tests 4-A, B, C. Layup ±45° Axial Only Hoop Response, Rosette No. 3

A - Test 4-A
B - Test 4-B
C - Test 4-C

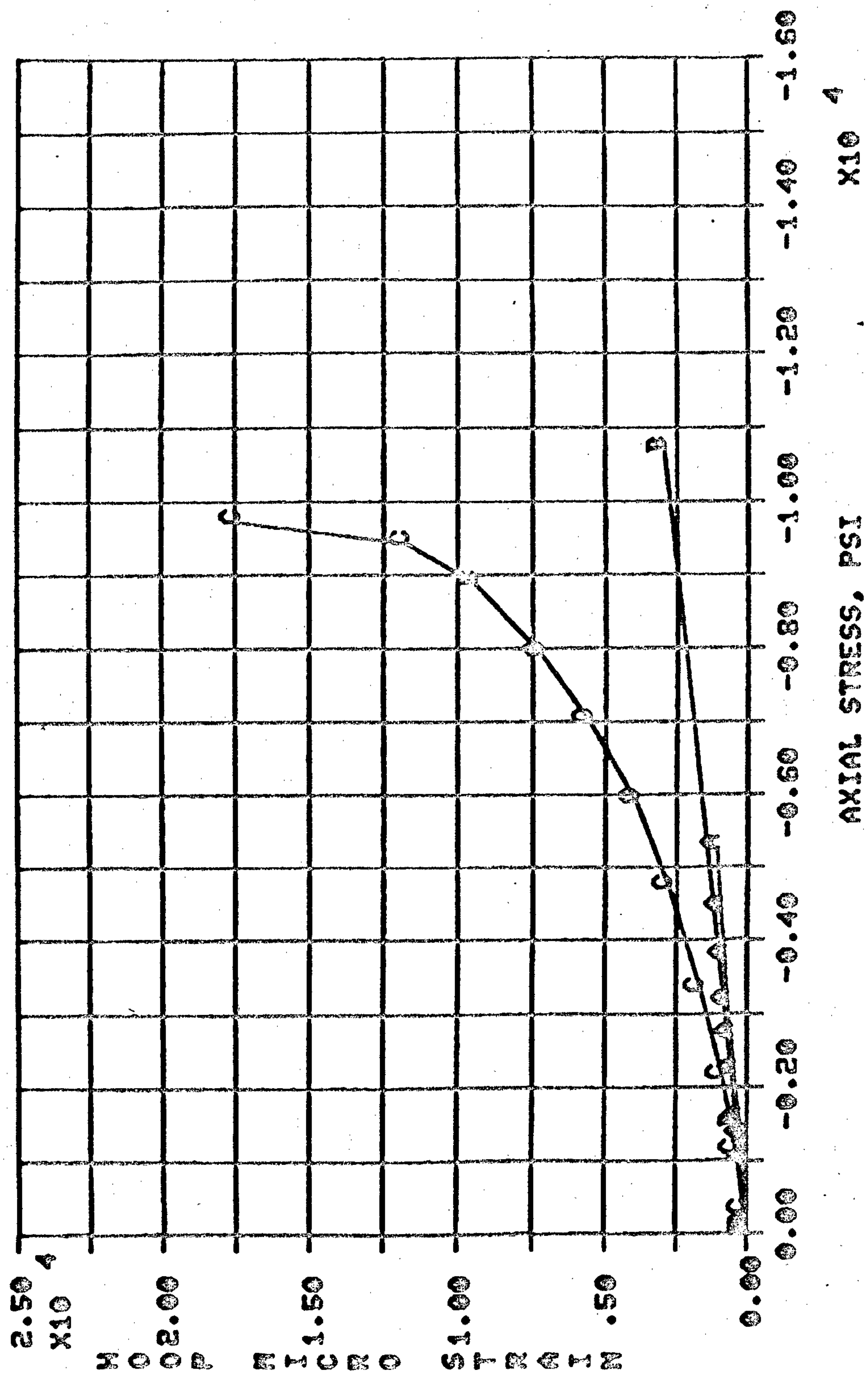


Figure 67 Tests 4-A, B, C. Layup ±45° Axial Only
Hoop Response, Rosette No. 4

A - Test 4-A
B - Test 4-B
C - Test 4-C

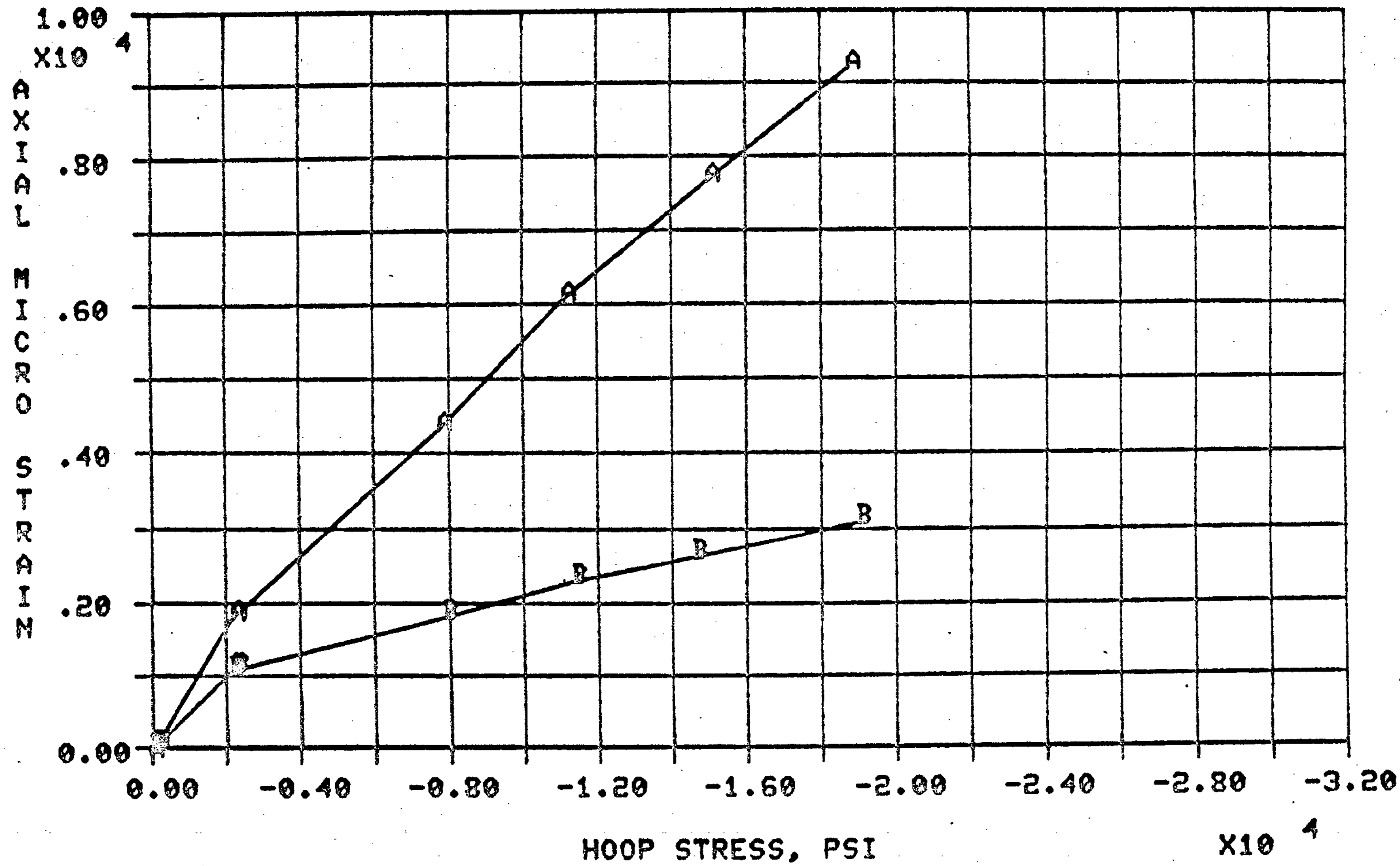


Figure 68 Test 5. Layup ±45° Ext. Pressure
Axial Response

A - Rosette No. 5
B - Rosette No. 6

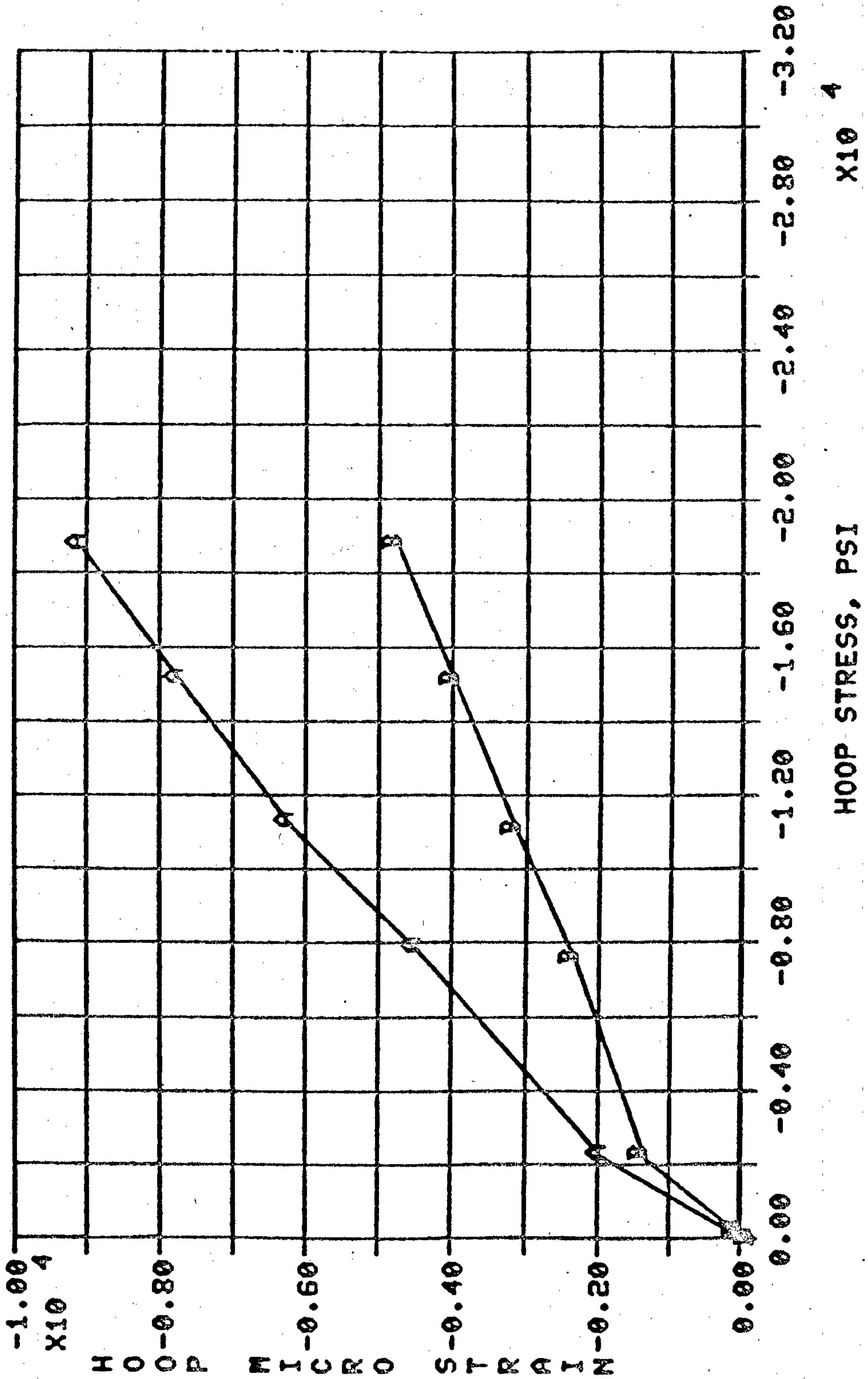


Figure 69 Test 5. Layup ±45° Ext. Pressure Hoop Response

A - Rosette No. 5
B - Rosette No. 6

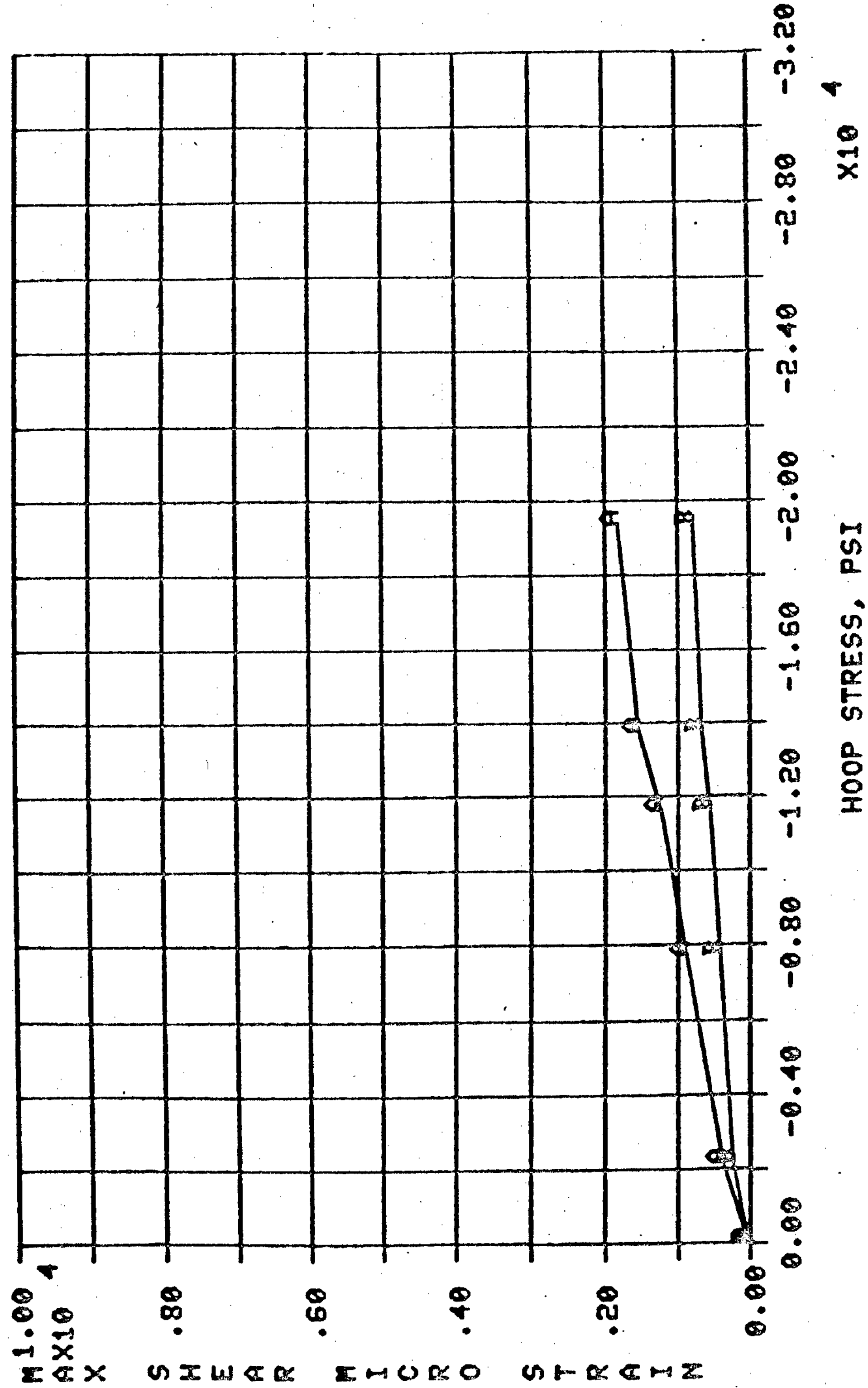


Figure 70 Test 5. Layup ±45° Ext. Pressure
Max. Shear

A - Rosette No. 5
B - Rosette No. 6

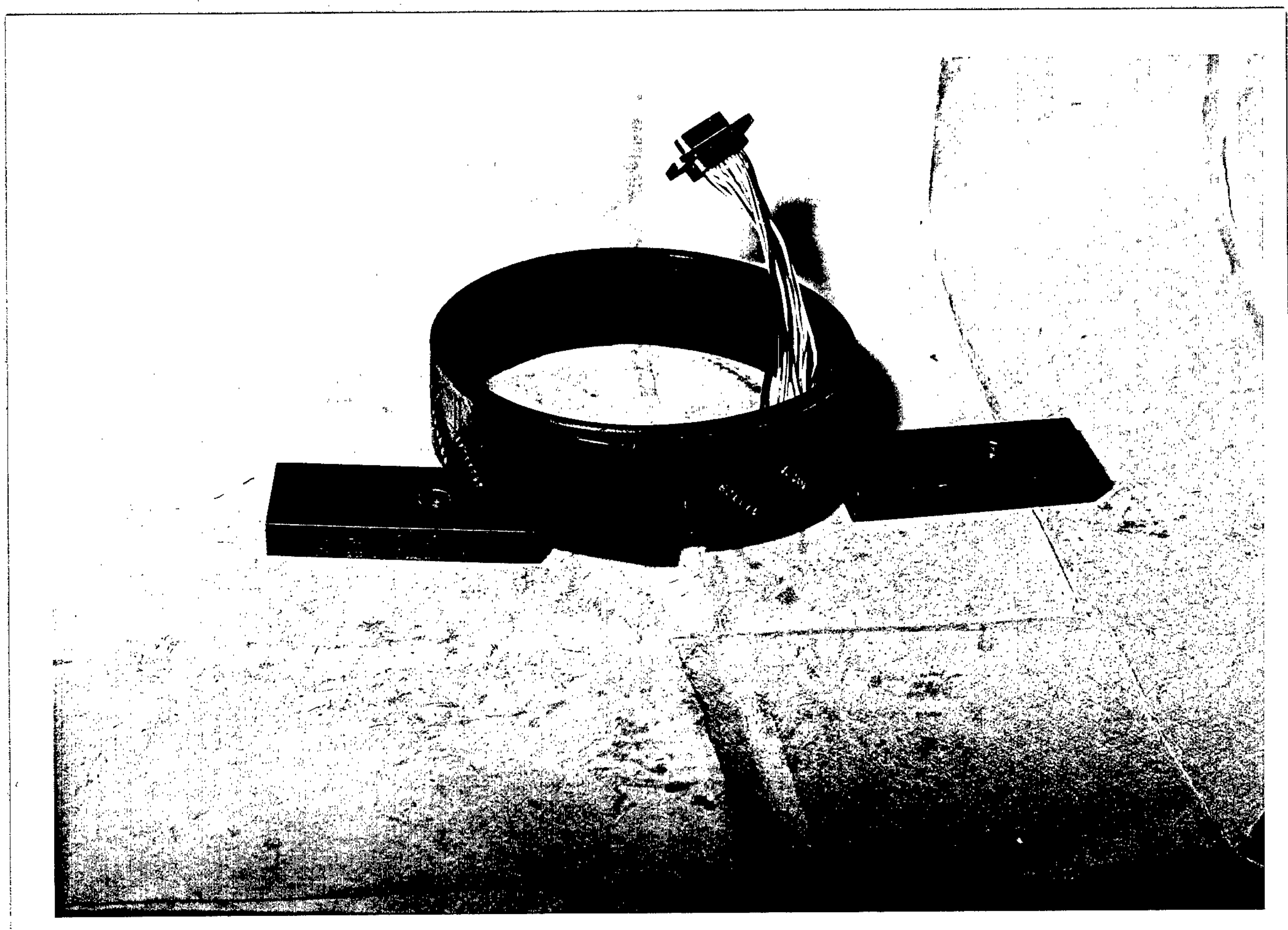

Figure 71 Test Specimen Used in Tests 4-A, 4-B, 4-C and 5 After Fracture from External Pressure. Ply Layup is ±45°.

Both internal pressure and axial load were applied to the specimen for Test 6. The internal pressure was manually servoed to the axial load such that a pure shear condition existed in the specimen. Figure 72 is a plot of the hoop stress versus axial stress. The layup for this specimen was 0°/±45°/90°. Figure 73 is a comparison plot of the axial strain versus axial stress for the rosettes located at the center of the specimen on the outside surface. Strains from Rosette Nos. 1 and 3 are in excellent agreement, and the strain in Rosette No. 2 is very close to these strains. Figure 74 is the axial response of the rosettes located at the edge of the specimen. The strains for these rosettes do not agree with each other. Also, these strains are two to four times higher than the strains recorded at the center of the specimen (see Figure 73). Figures 75, 76 and 77 are comparison plots of hoop strain versus hoop stress with the rosettes located at the center of the specimen on the outside surface, the inside and outside comparison rosettes and the edge rosettes, respectively. The gages at the center on the outside surface are in good agreement, as were the gages at the edge of the specimen. However, the gages recorded strains approximately twice as large as the center gages. The inside-outside comparison gages were in very poor agreement. The maximum shear strain plots for this test were uninterpretable and are not reproduced here. The final failure in Test 6, shown in Figure 78, was from a fracture running approximately half-way across the specimen at a 45° angle. The fracture then changed directions and propogated the remainder of the way across the specimen in an axial direction. The final fracture was accompanied by eight 45° partial fractures distributed around the specimen.

Test 7 was to be conducted such that hoop stress equaled axial stress. The loads were applied using external pressure and axial load. The specimen layup was 0°/±45°/90°. Figure 79

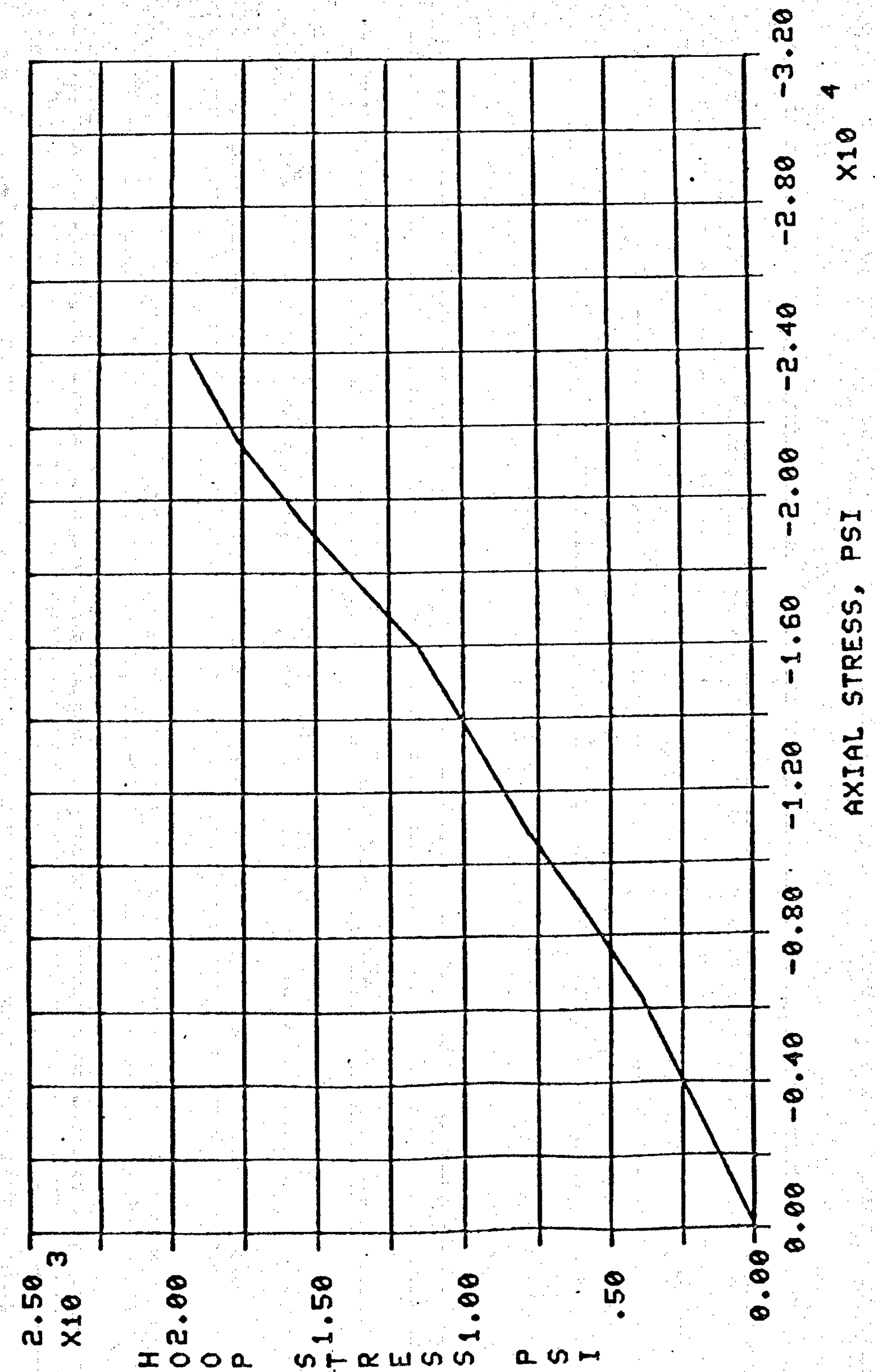


Figure 72 Hoop Stress Versus Axial Stress for Test 6

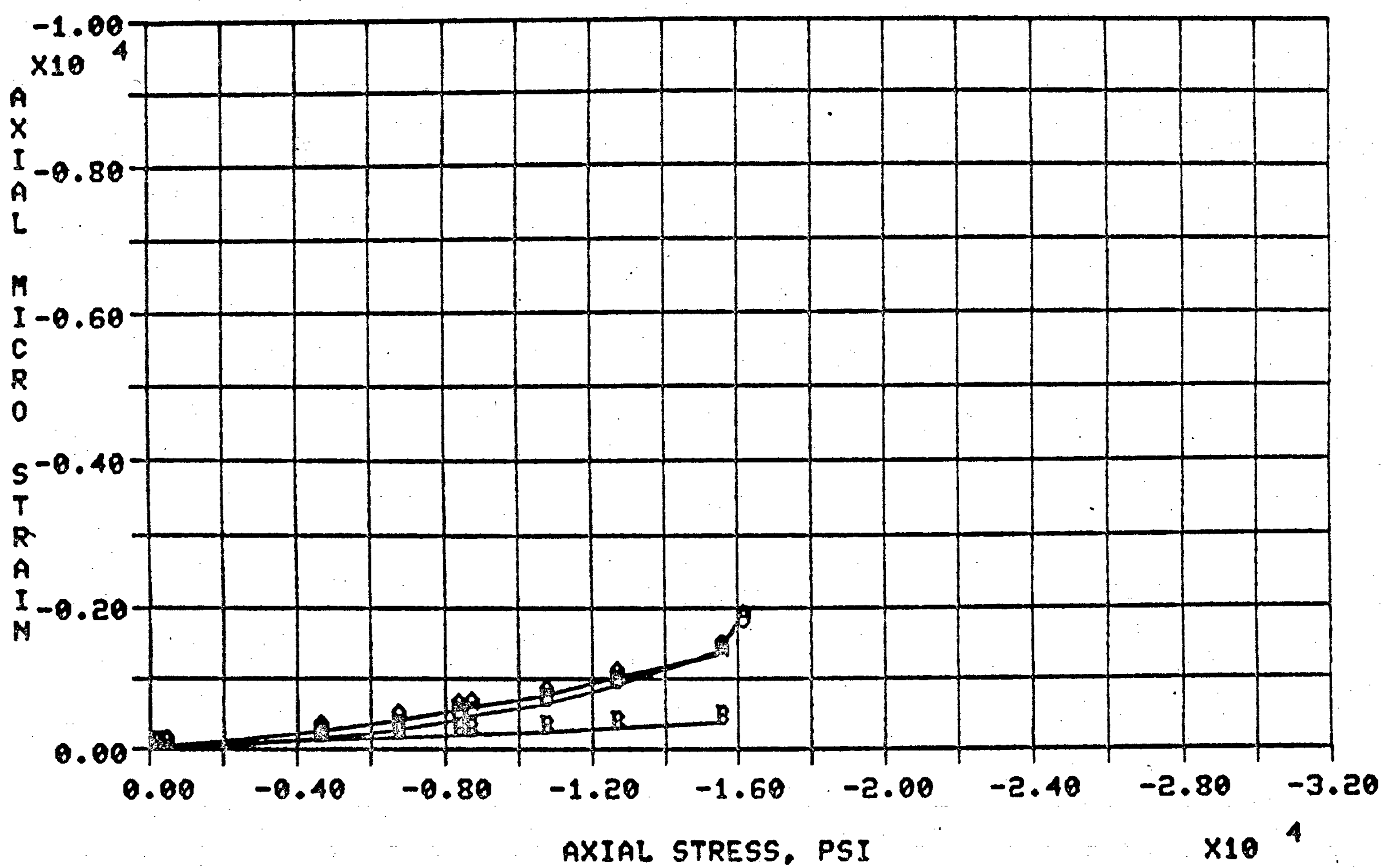


Figure 73 Test 6. Layup 0°/±45°/90° Pure Shear Load Axial Response, Outside Rosettes

A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3

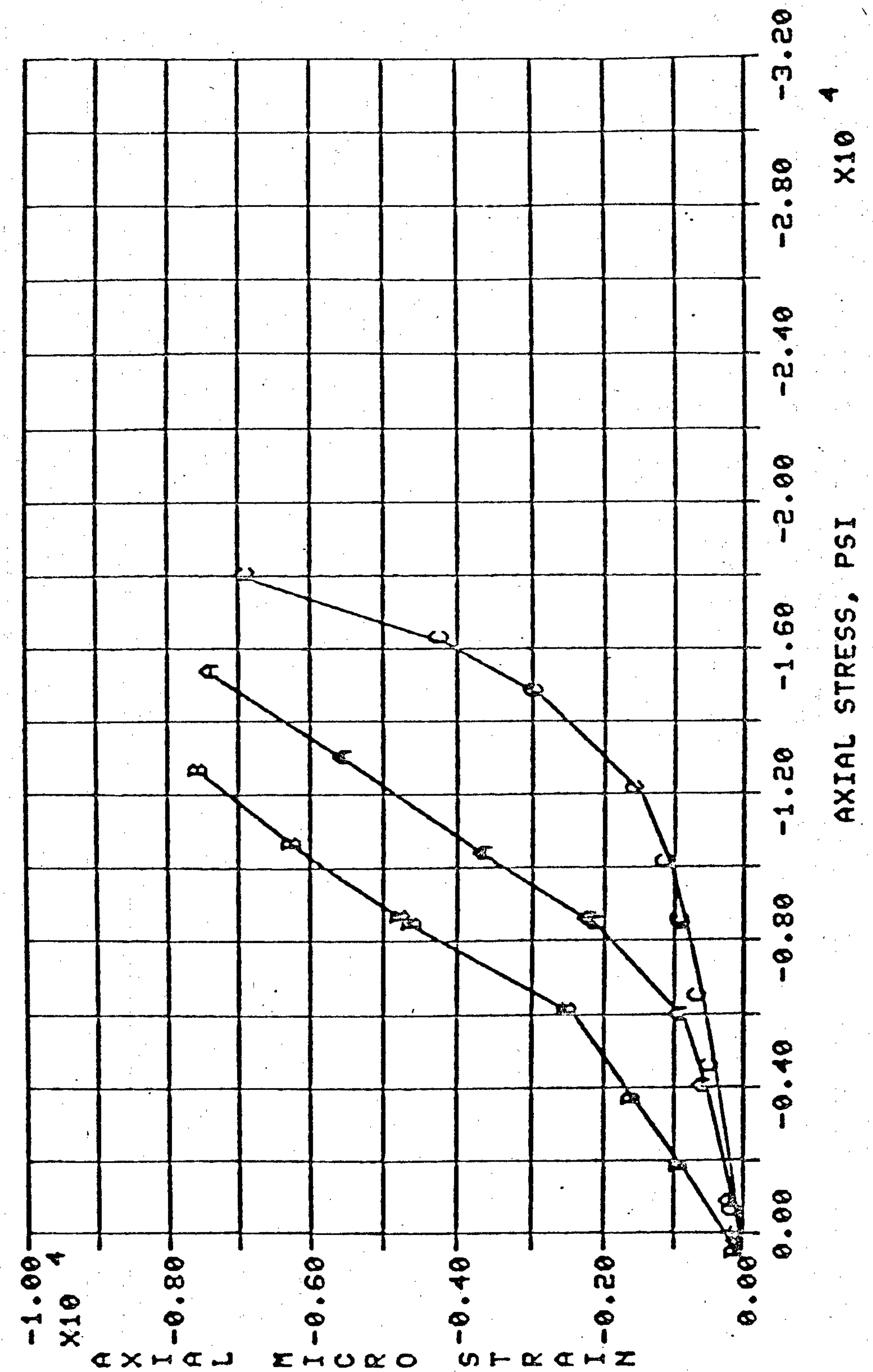


Figure 74 Test 6. Layup 0°/±45°/90° Pure Shear Load
Axial Response, Edge Rosettes

A - Rosette No. 6
B - Rosette No. 7
C - Rosette No. 8

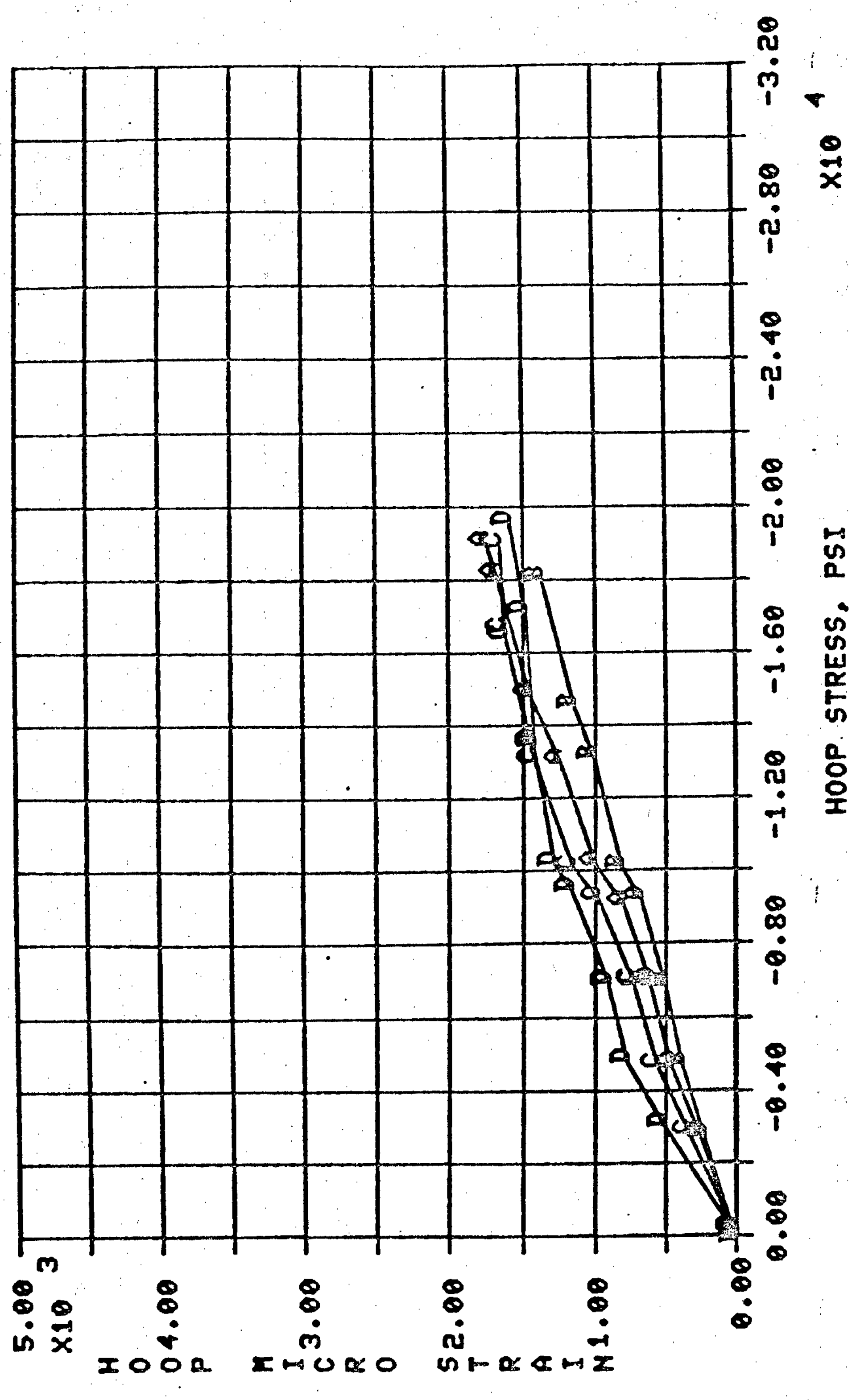


Figure 75 Test 6. Layup 0°/±45°/90° Pure Shear Load
Hoop Response, Outside Rosettes

A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4

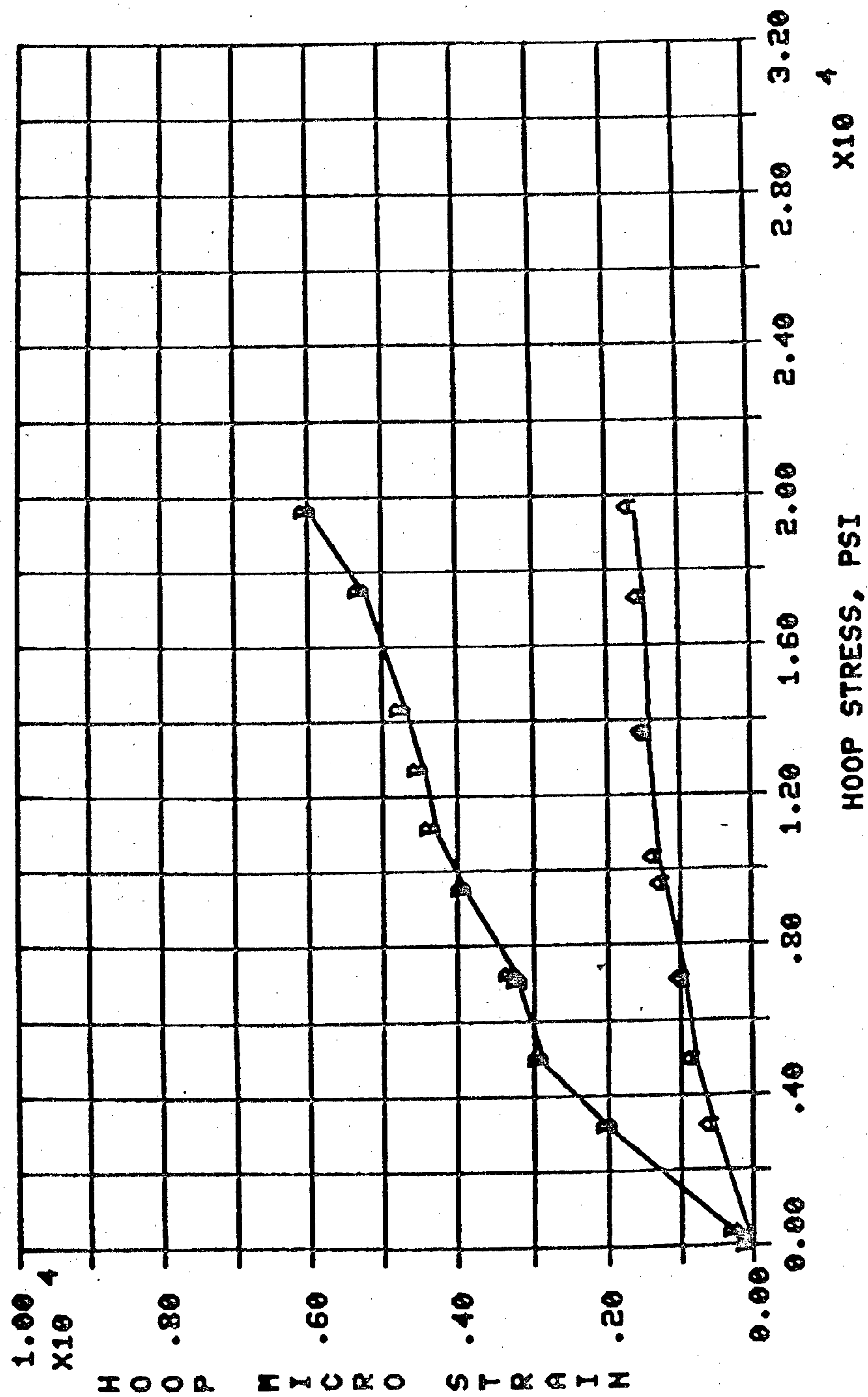


Figure 76 Test 6. Layup 0°/±45°/90° Pure Shear Load
Hoop Response, Inside/Outside Rosettes
Least Squares Fit

A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)

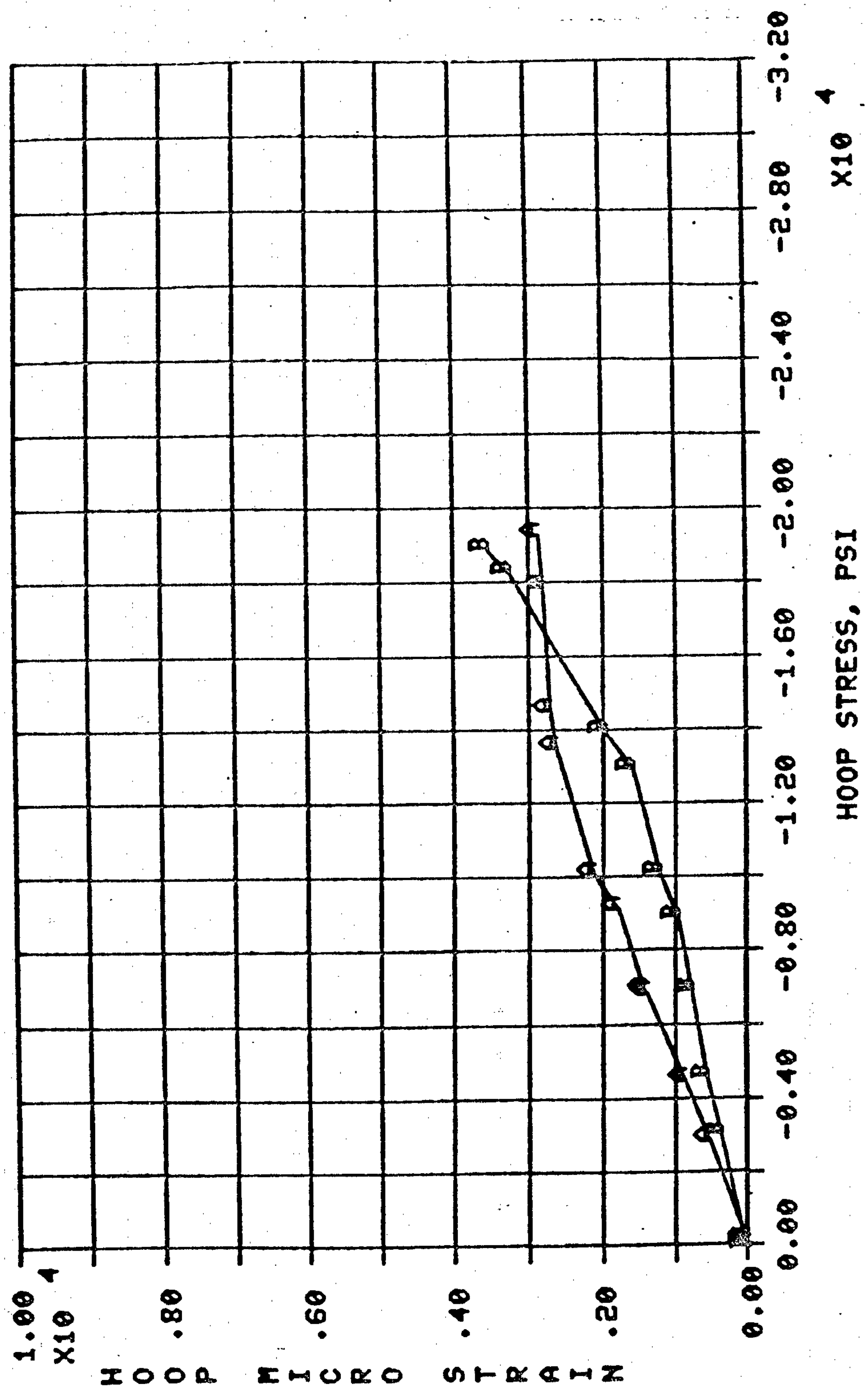


Figure 77 Test 6. Layup 0°/±45°/90° Shear Load
Hoop Response, Edge Rosettes

A - Rosette No. 7
B - Rosette No. 8

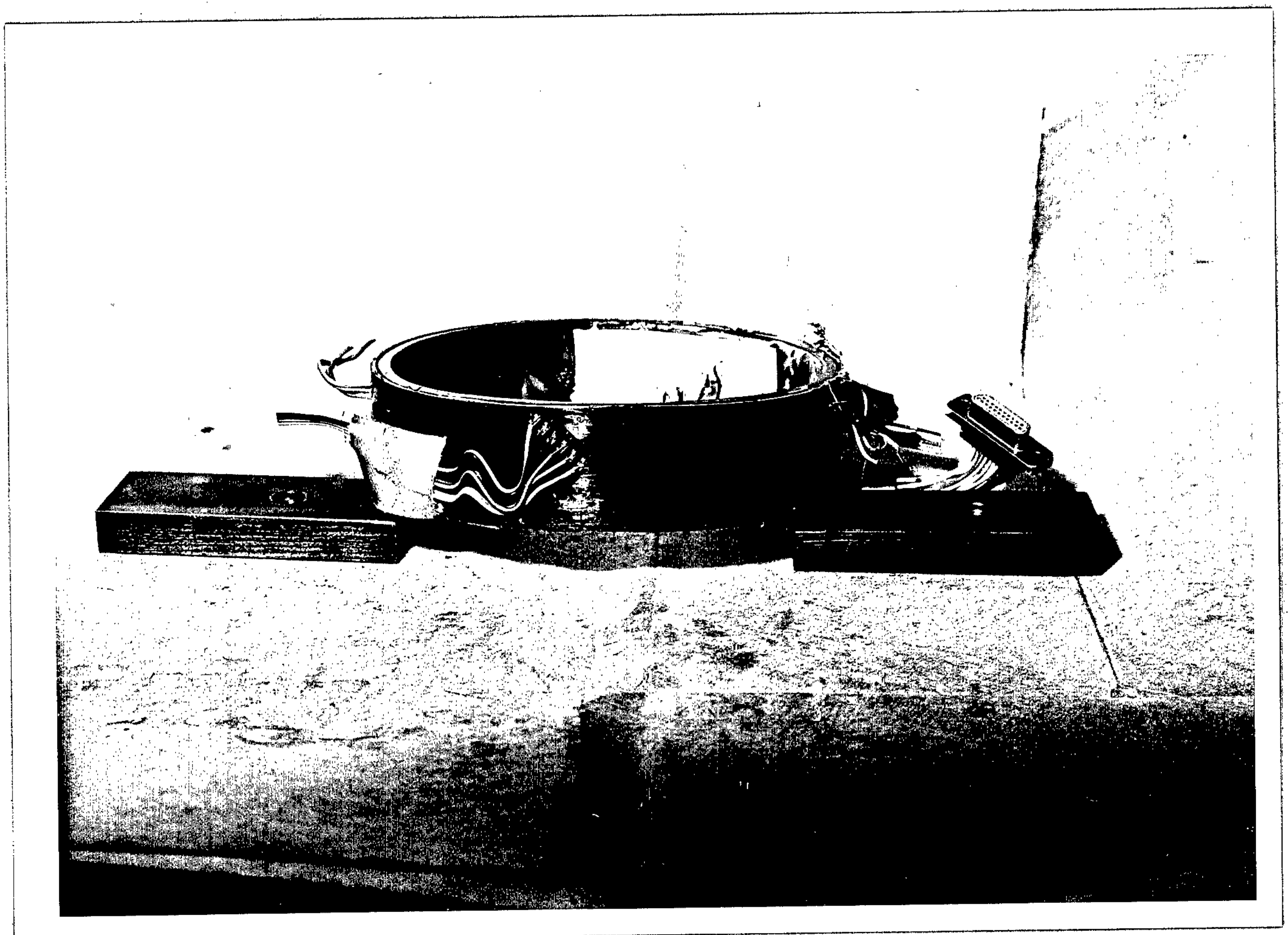

Figure 78 Test Specimen No. 6 After Failure from Internal Pressure and Axial Load. Stress Conditions were Equivalent to Pure Shear. Ply Layup is 0°/±45°/90°.

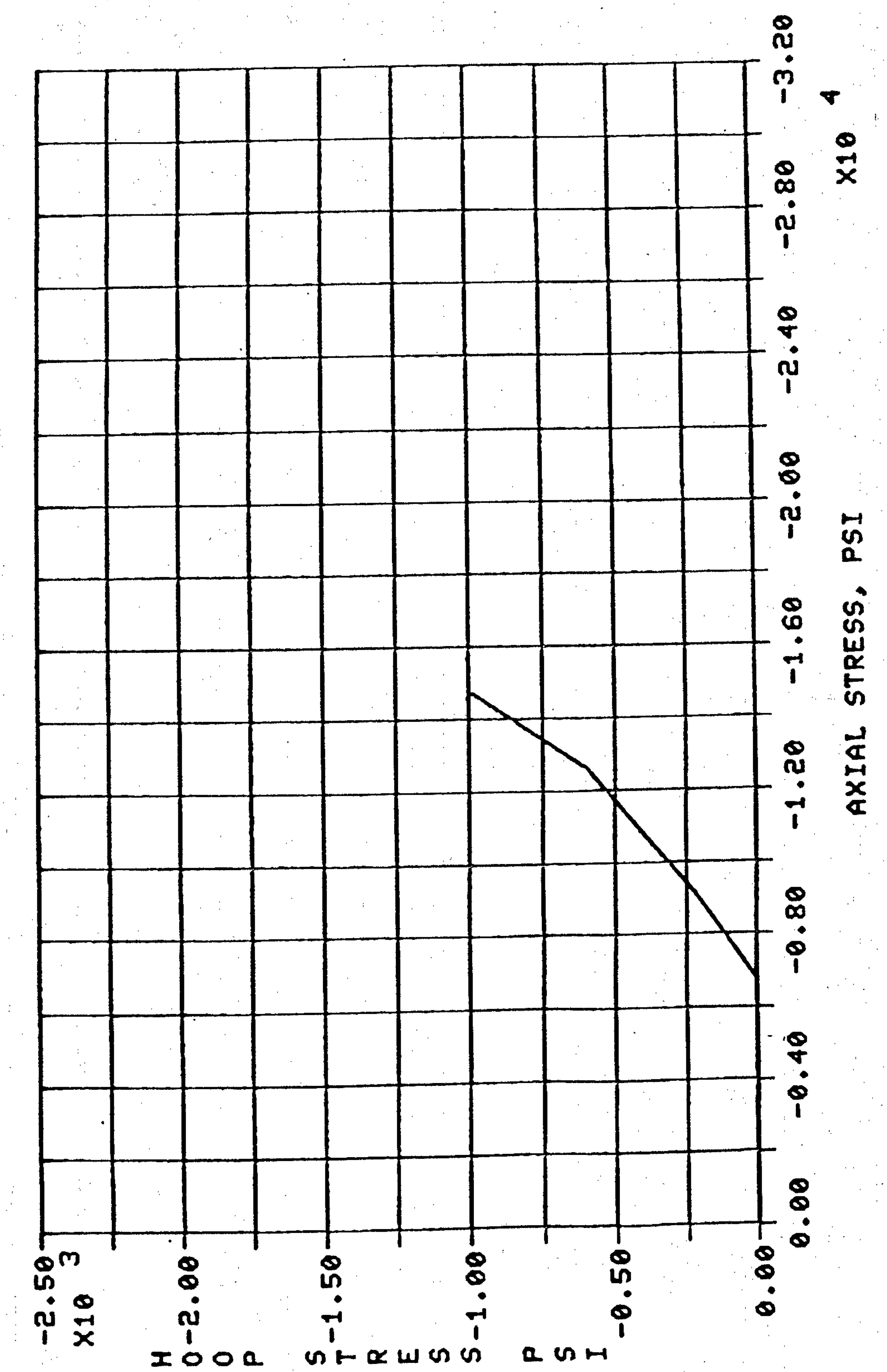


Figure 79 Hoop Stress Versus Axial Stress for Test 7

is a plot of the hoop stress versus axial stress. An axial stress of 7000 psi compression was applied to the specimen before any external pressure was applied. The external pressure was manually servoed to the axial load. In the future, this type of test (test with a loading manually servoed) should be conducted much slower to allow adequate reaction time. Strain gage output during Test 7 was erratic. As the specimen could not be observed through the external pressure collet, it is not known with certainty why the erratic strains arose. Figures 80 through 86 are the comparison strain plots for this test. Very poor agreement was obtained between the gages located along the outside center of the specimen; however, the gages between the inside and outside surfaces produced axial results in agreement. The remaining results from this test indicate that hourglassing or buckling could have been taking place. Figure 87 is a photograph of the specimen used in Test 7 after failure occurred.

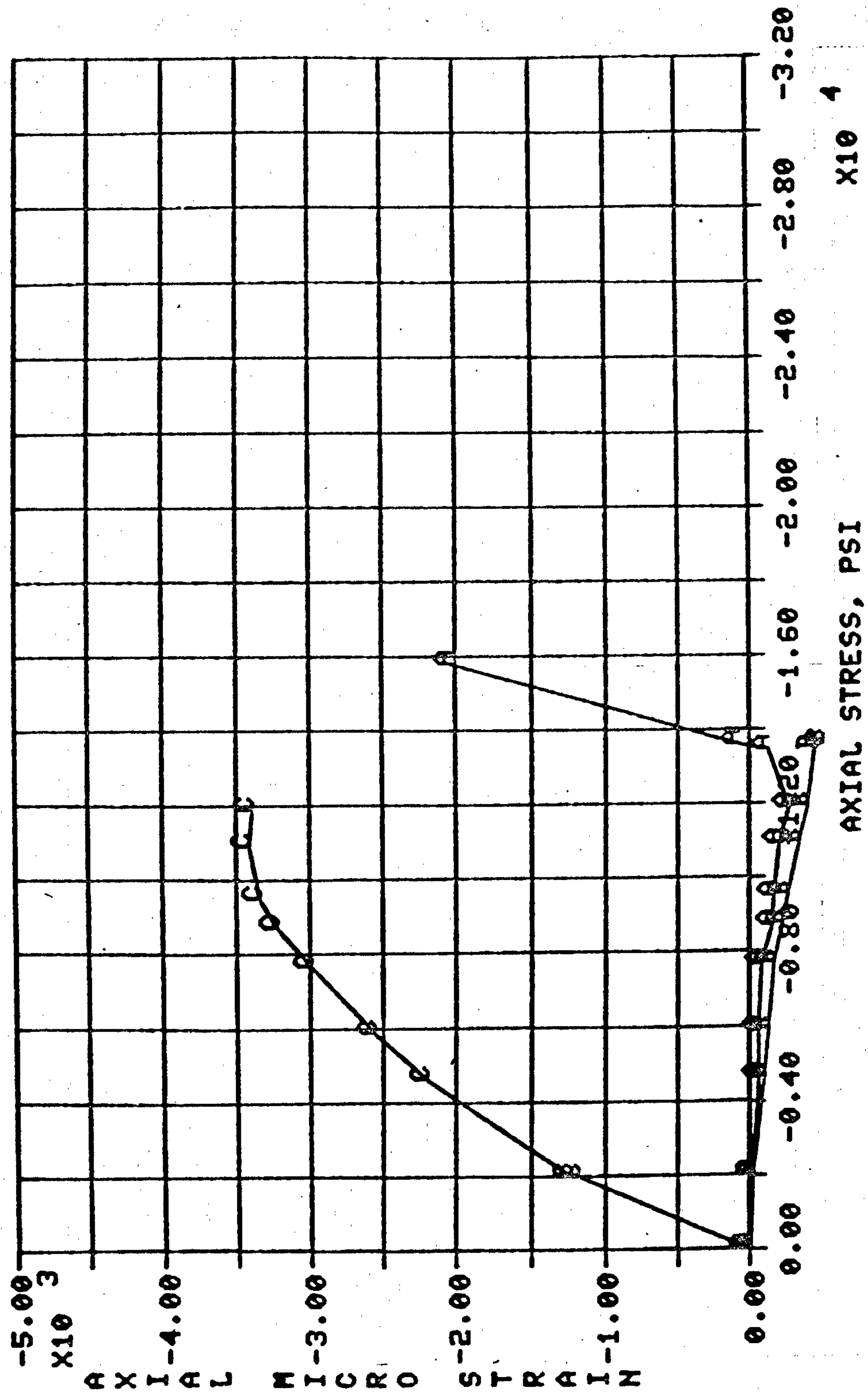


Figure 80 Test 7. Layup 0°/±45°/90° Axial ε Ext. Pr. Axial Response, Outside Rosettes

A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3

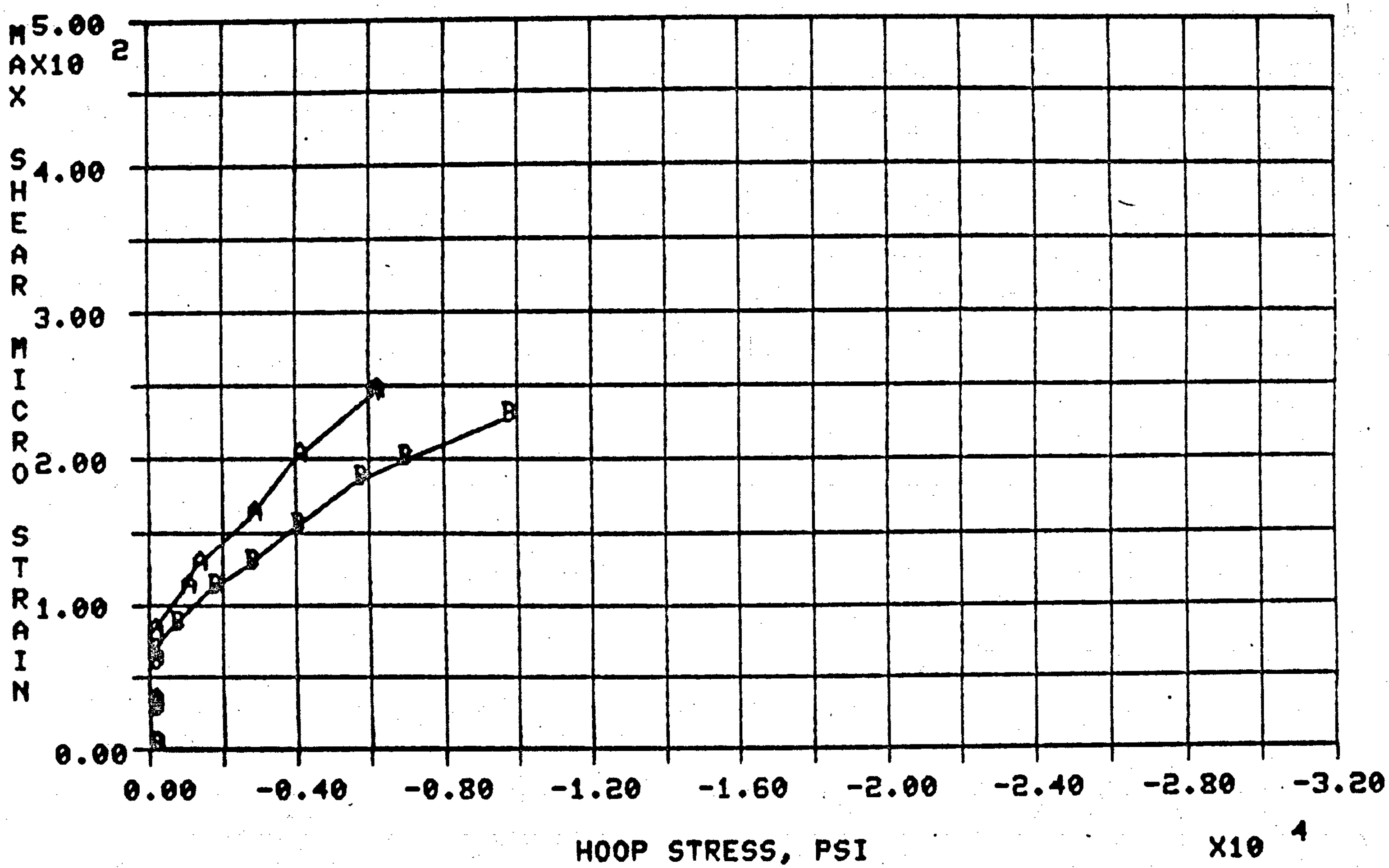


Figure 81 Test 7. Layup 0°/±45°/90° Axial & Ext. Pr.
Max. Shear, Outside Rosettes

A - Rosette No. 1
B - Rosette No. 2

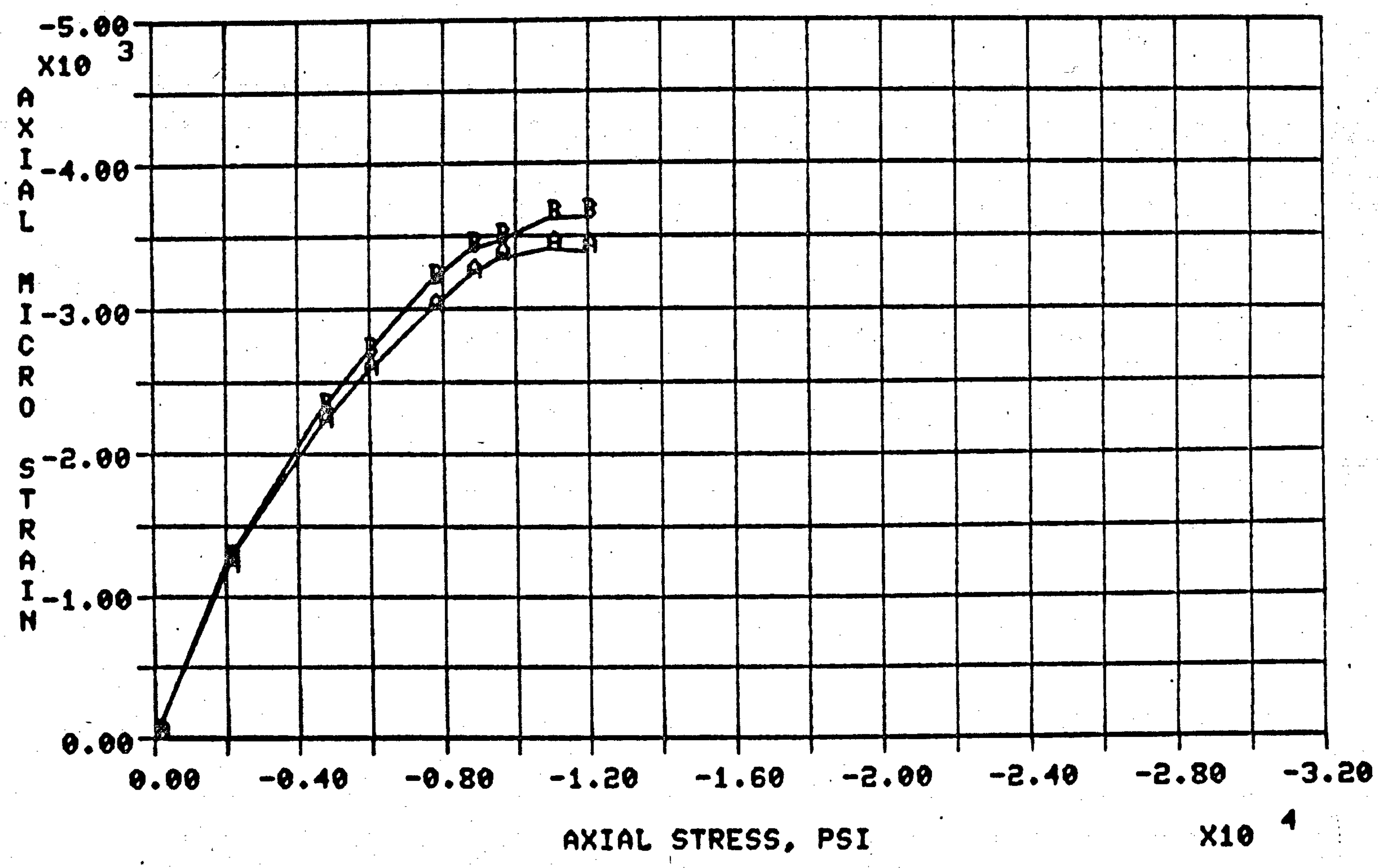


Figure 82 Test 7. Layup 0°/±45°/90° Axial & Ext. Pr.
Axial Response, Inside/Outside Rosettes

A - Rosette No. 4 (outside)
B - Rosette No. 5 (inside)

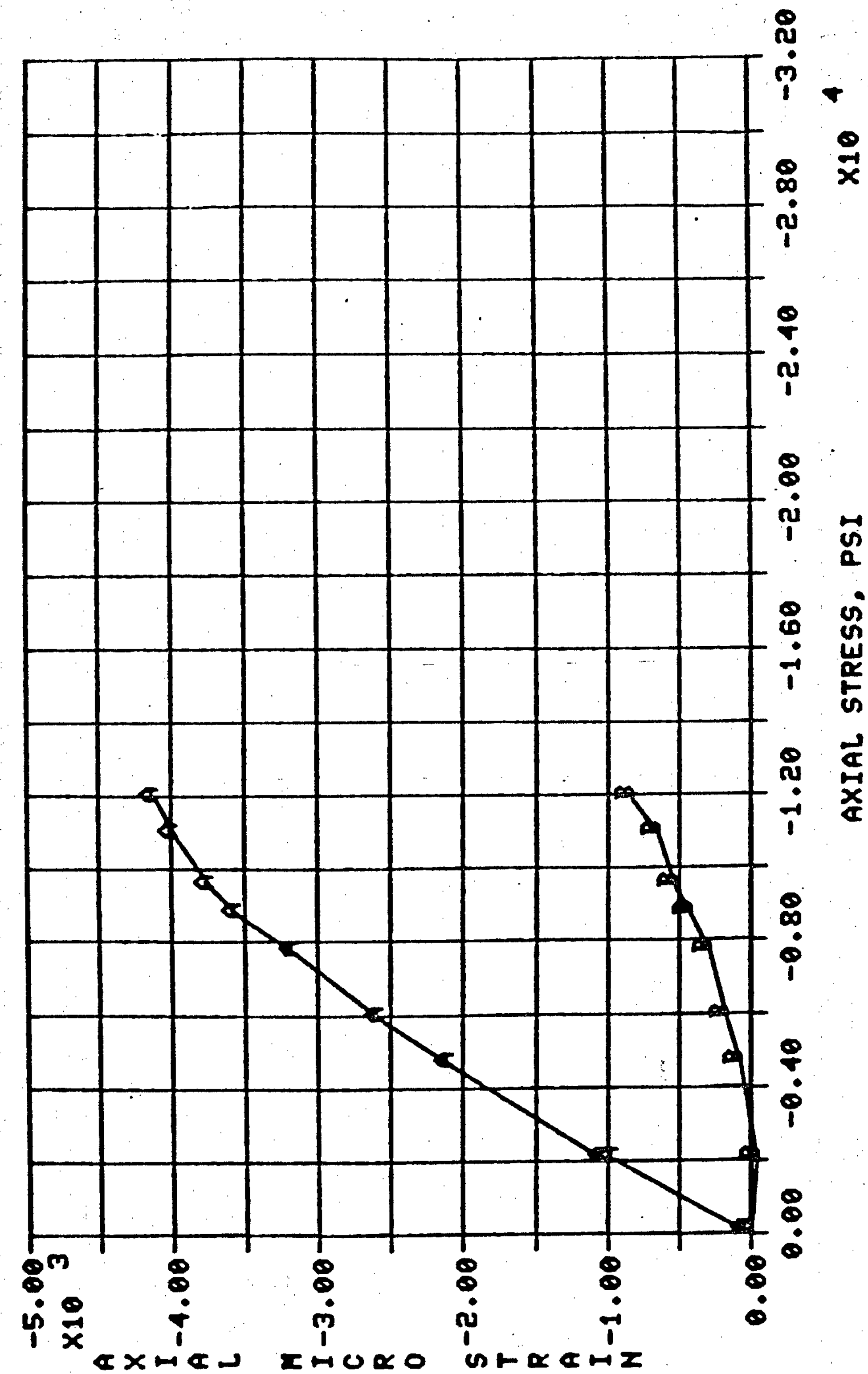


Figure 83 Test 7. Layup 0°/±45°/90° Axial & Ext. Pr.
Axial Response, Edge Rosettes

A - Rosette No. 7
B - Rosette No. 8

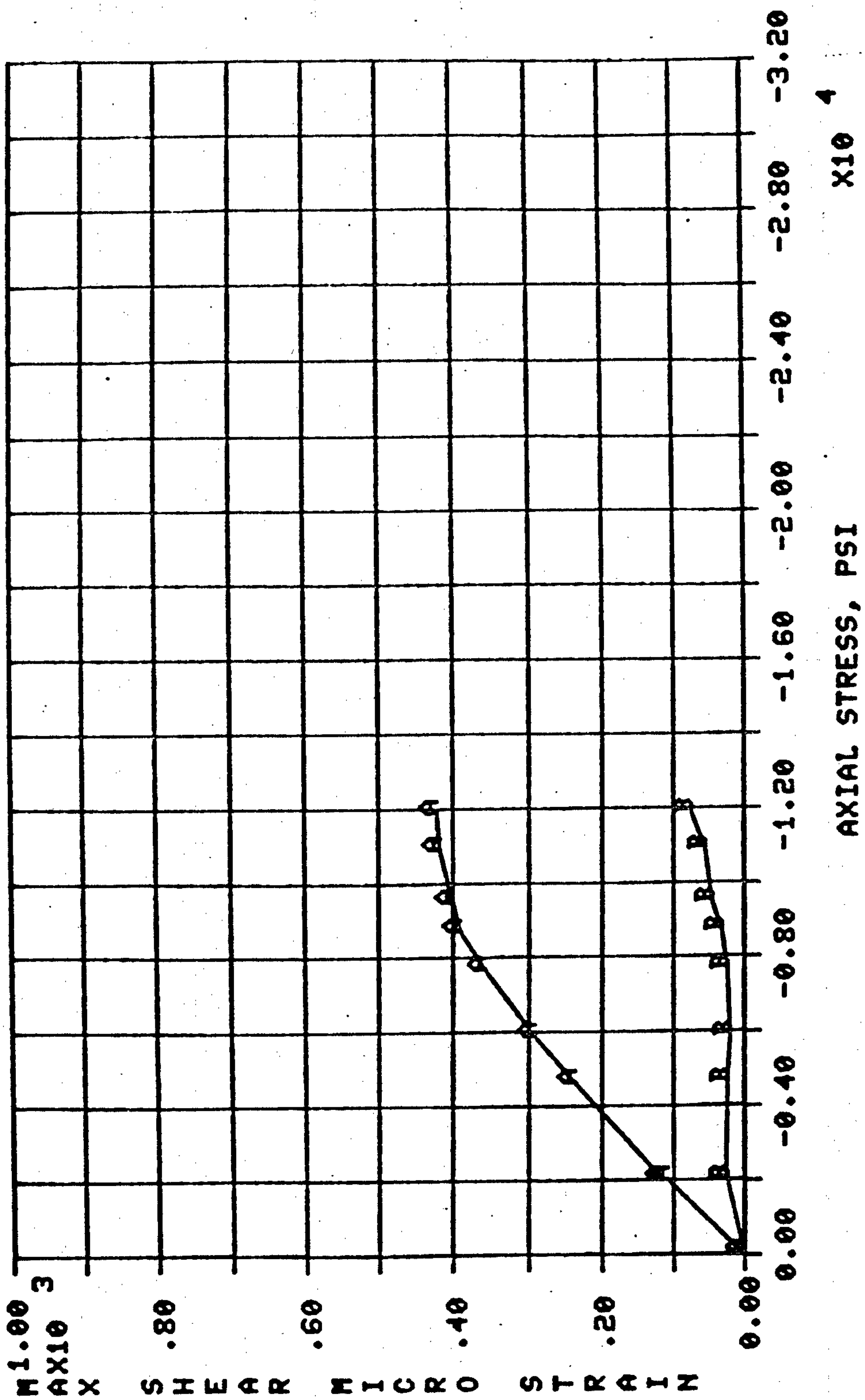


Figure 84 Test 7. Layup 0°/±45°/90° Axial & Ext. Pr.
Max. Shear, Edge Rosettes

A - Rosette No. 7
B - Rosette No. 8

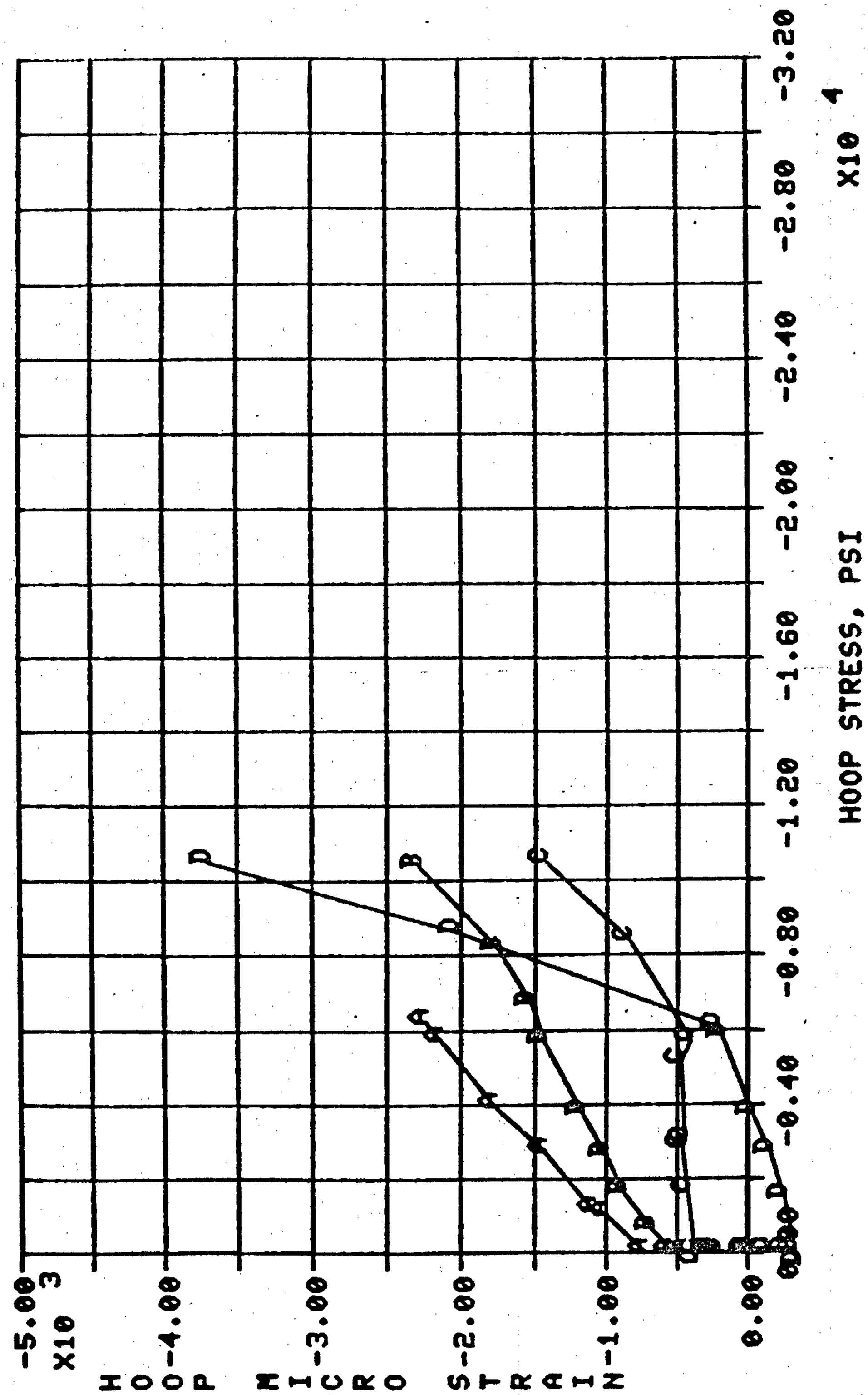


Figure 85  Test 7. Layup 0°/±45°/90° Axial & Ext. Pr.
Hoop Response, Outside Rosettes

A - Rosette No. 1
B - Rosette No. 2
C - Rosette No. 3
D - Rosette No. 4

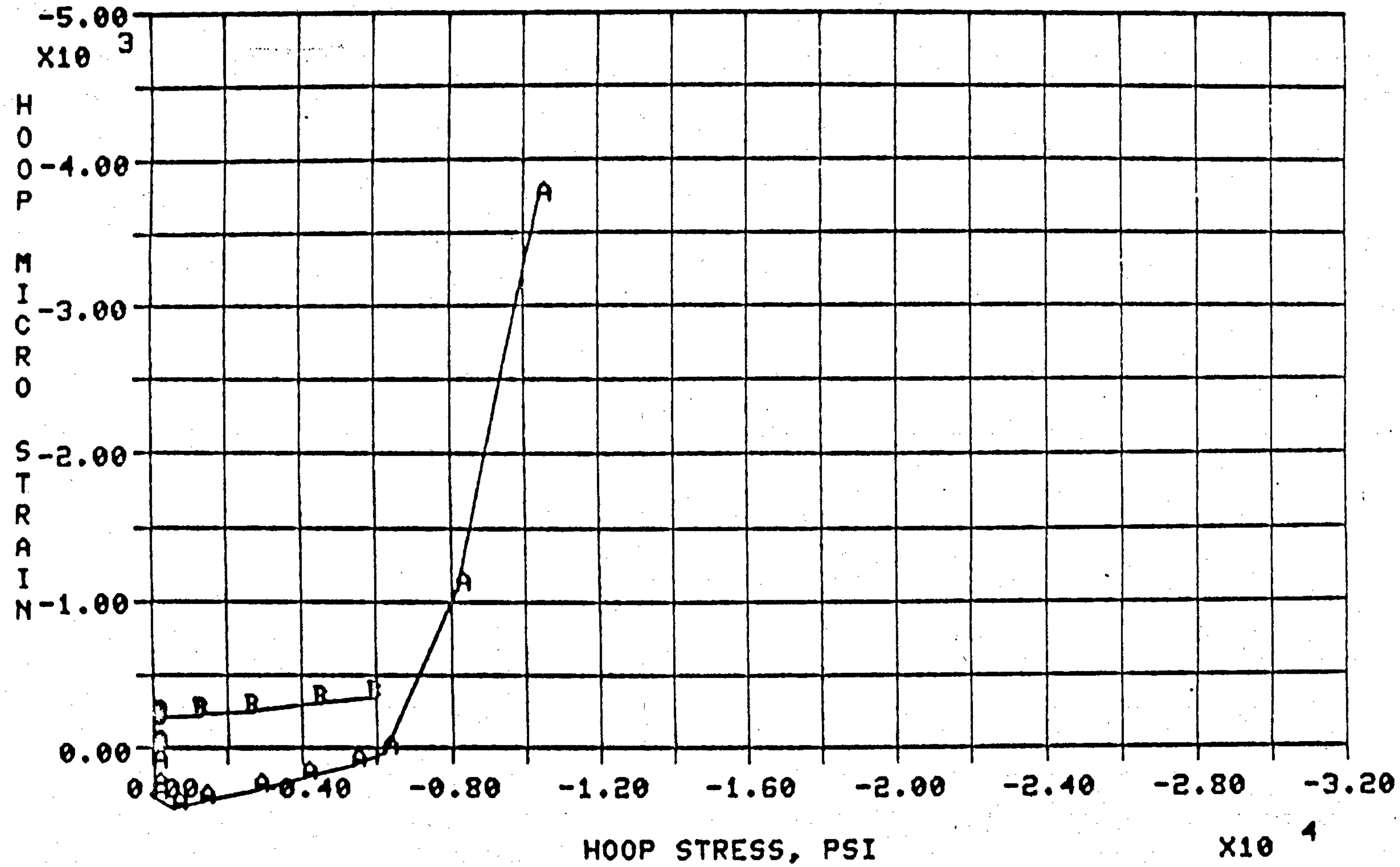


Figure 86 Test 7. Layup 0°/±45°/90° Axial & Ext. Pr.
Hoop Response, Edge Rosettes

A - Rosette No. 7
B - Rosette No. 8

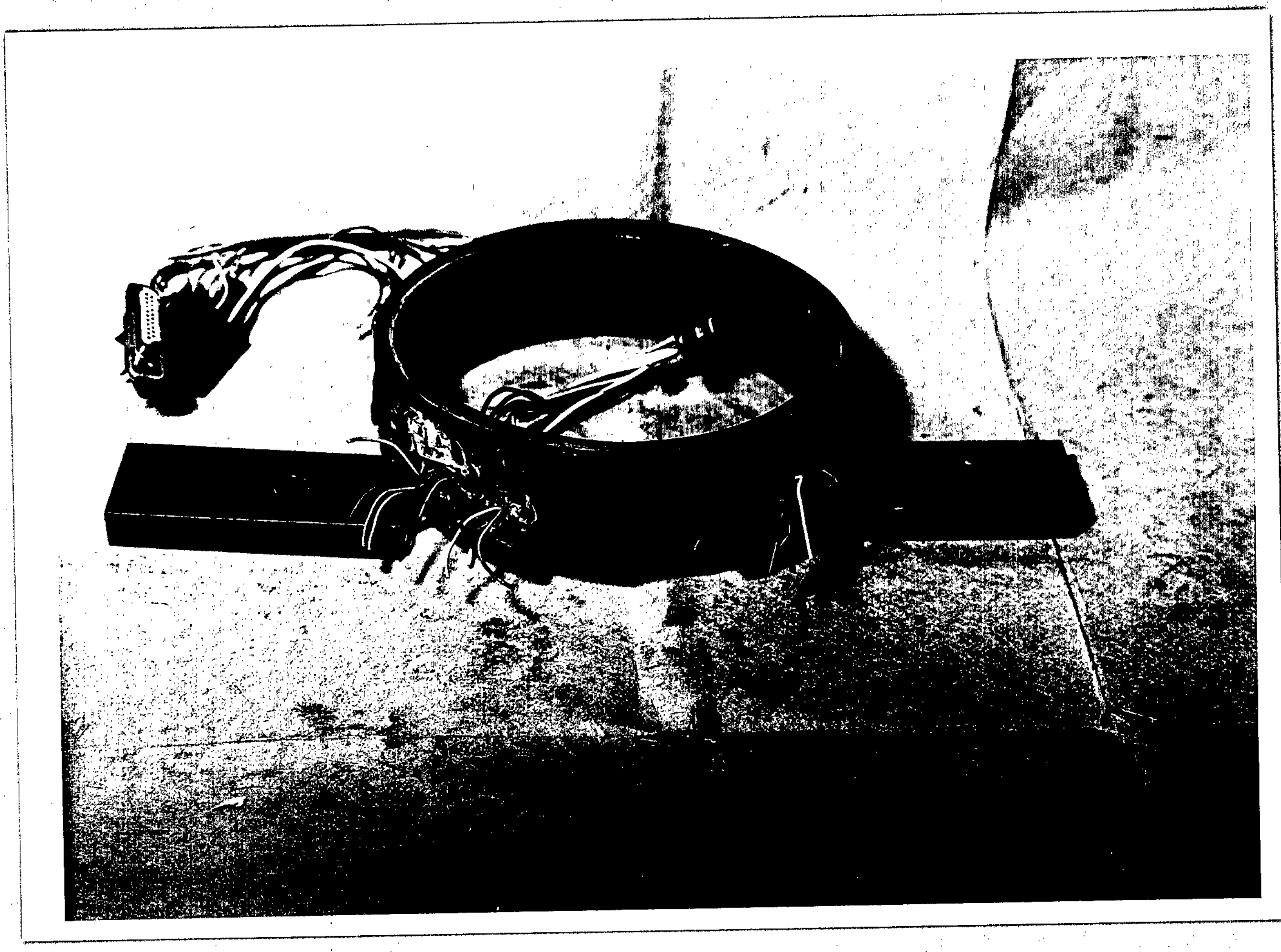

Figure 87 Test Specimen No. 7 After Failure from Axial Load and External Pressure. Stress Conditions Were Such That Axial Stress Equaled Hoop Stress. Ply Layup is $0°/\pm 45°/90°$.

## V. CONCLUSIONS

Based on the testing, the test technique has been shown to be promising as a simple test system for determining the biaxial properties of materials. In the early elastic regime, elastic properties may be determined for compression-compression, as well as for tension-compression. The fixture has demonstrated its ability to apply axial compression, internal or external pressure, or a combination of loadings. It appears that the solid lubricant system works well in retaining the pressure while allowing the ends to be relatively free of constraint.

Although the fixture was originally designed for biaxial tests, it has been shown to be capable of rupturing high Poisson's ratio tubes under internal pressure. This is possible as the platens may be advanced as the specimen length decreases so that no gap appears and oil pressure is maintained. Prior to the development of this fixture, free end constraint internal pressure tests on high Poisson's ratio tubes could not be performed.

The tests to date have only demonstrated that the testing technique is very promising. Additional tests need to be performed to improve the fixture and demonstrate repeatability of the results on identical specimens. Different length specimens, such as .5 inches and 2.0 inches, should be tested.

# APPENDIX A

## LISTING OF
## COMPUTER PROGRAM
## "STRAINS"

## COMPUTER PROGRAM "STRAIN"

As part of the effort reported here, a computer program was developed for processing strain gage data. The program is specifically tailored to the Sun System used by Anamet for monitoring and digitizing strain gage data readings. It is presently running on Anamet's PDP 11/34 under RSX-11M, in an interactive mode. All the plots reproduced in this report were generated by the computer on a Tektronix 4014 display screen.

STRAIN operates in two phases. First, a raw data file, which has been transferred directly from the Sun System to disk, is read and checked for format errors and for overload or open circuit conditions. The information is sorted by channels and stored in a binary disk file. The user is asked to identify each channel as either a load channel or a strain channel. For strain channels, the rosette number and the leg of the rosette are requested. Raw data files may consist of one or more test runs, each with different assignments of data channels. Once the binary file has been established, the second phase may be executed repeatedly to obtain plots and/or print-outs of reduced data.

In the second phase, the user is asked to supply the constants required to convert load data to stresses, thus making the program independent of the geometry of the specimen. Two load channels are provided for: an axial force channel and a pressure channel. Eight rosettes are allowed. For each plot to be generated, the user may choose to plot either stresses or strains on either axis. These may be direct stresses and strains, or principal stresses and strains, calculated by the program. As many as eight curves may be drawn on a single plot, with the user choosing a different rosette for each curve, and if the data file contains multiple runs, the curves may be selected from different runs. The user is also given the option to print the data that is plotted. The values plotted on the vertical axis are interpolated to agree with the times corresponding to the values on the horizontal axis.

```
FORTRAN IV      V02.04          FRI 04-JAN-80 09:46:52          PAGE 001
CORE=31K, UIC=(212,1)                                 ,STRAIN/EX=STRAIN

0001          PROGRAM STRAIN
        C
        C     PROGRAM TO DIGEST AND PLOT DATA FROM SUN SYSTEM
        C
0002          COMMON/MISC/NRUN,TLD(10,2),TDIR(10,3),JOBTIT(60)
0003          BYTE TLD,TDIR,JOBTIT
0004          COMMON/CONTROL/REPEAT,JPLT(2)
0005          LOGICAL REPEAT
0006          COMMON/BINARY/STUFF(19932)
0007          BYTE STUFF,FNAME(30)
0008          EQUIVALENCE (STUFF,FNAME)
0009          COMMON/SLD/SL(3,2,2)
0010          LOGICAL WANT,NEW
0011          DATA LSTUFF/19932/
0012          CALL ERASE
0013          CALL CLEAR(SL,24)
0014          CALL DISPLAY
             1('ANAMET SUN SYSTEM STRAIN GAGE DATA REDUCTION & PLOTTING PROGRAM')
0015          REPEAT=.FALSE.
0016          CALL DISPLAY('NOTE: TO SELECT DEFAULT INPUT VALUES, STRIKE RETURN')
0017          CALL PAUSE
0018          NEW=.NOT.WANT
             1('HAS A BINARY FILE ALREADY BEEN CREATED FOR THIS JOB')
0019          IF (NEW)
             1CALL ASSIGN(1,FNAME,ISREAD('RAW DATA FILE NAME',FNAME,3,30))
0021          CALL ASSIGN(2,FNAME,ISREAD('BINARY DATA FILE NAME',FNAME,3,30))
0022          CALL DISPLAY
             1('IF NO PRINT FILE IS WANTED, TYPE "NL:" IN RESPONSE TO THE FOLLOWING:')
0023          CALL ASSIGN(3,FNAME,ISREAD('PRINT FILE NAME',FNAME,3,30))
0024          IF (.NOT.NEW) GO TO 30
0026          N=ISREAD('JOB TITLE',JOBTIT,1,60)
        C
        C     GET INFO FROM USER ON NEW FILE
        C
0027          CALL DISPLAY
             1('PROGRAM ALLOWS TWO LOAD CHANNELS')
0028          CALL DISPLAY
             2('PLEASE CHARACTERIZE EACH LOAD CHANNEL')
0029          CALL DISPLAY
             3('(E.G. AXIAL OR PRESSURE OR UNUSED)')
0030          N=ISREAD('NAME OF LOAD TYPE 1',TLD(1,1),1,10)
0031          N=ISREAD('NAME OF LOAD TYPE 2',TLD(1,2),1,10)
0032          CALL DISPLAY
             4('THE PROGRAM ALSO EXPECTS THREE STRAIN CHANNELS PER ROSETTE')
0033          CALL DISPLAY
             5('PLEASE CHARACTERIZE THE TWO NORMAL STRAIN DIRECTIONS')
0034          CALL DISPLAY
             6('(E.G. AXIAL OR HOOP OR TRANSVERSE)')
0035          N=ISREAD('NAME OF STRAIN DIRECTION 1',TDIR(1,1),1,10)
0036          N=ISREAD('NAME OF STRAIN DIRECTION 2',TDIR(1,2),1,10)
0037          ENCODE(10,5,TDIR(1,3))
0038    5     FORMAT (10H45 DEGREE )
0039          CALL PAUSE
        C
```

```
      C      READ IN RAW DATA
      C
0040         DO 10 NRUN=1,1000
0041         IF (RAWDAT(NRUN).LT.0.0) GO TO 20
0043   10    CONTINUE
0044   20    NRUN=NRUN-1
0045         WRITE(2) NRUN,TLD,TDIR,JOBTIT
0046         CALL CLOSE(1)
0047         GO TO 40
0048   30    CALL GETDAT(0)
0049         CALL GETDAT(-1)
0050         CALL REVIEW
      C
      C      KEEP PLOTTING TILL USER WEARS OUT
      C
0051   40    CALL PLTGEN
0052         REPEAT=.TRUE.
0053   50    CALL PLOTIT
0054         IF (WANT('WANT TO FIT A CURVE')) CALL CURFIT
0056         IF (.NOT.WANT('WANT TO THROW OUT WILD POINTS')) GO TO 60
0058         CALL WILD
0059         GO TO 50
0060   60    IF (WANT('WANT ANY MORE PLOTS')) GO TO 40
0062         CALL DISPLAY('REMINDER: IF YOU GENERATED A PRINT FILE,')
0063         CALL DISPLAY(' PLEASE EITHER DELETE IT:')
0064         CALL DISPLAY('      >PIP FILENAME;*/DE')
0065         CALL DISPLAY(' OR SPOOL IT:')
0066         CALL DISPLAY('      >PIP FILENAME/SP')
0067         CALL CLOSE(2)
0068         STOP
0069         END
```

```
FORTRAN IV      V02.04          FRI 04-JAN-80 09:47:06          PAGE 001
CORE=31K, UIC=(212,1)                                    ,RAWDAT/EX=RAWDAT

0001          FUNCTION RAWDAT(NRUN)
        C
        C     ROUTINE READS RAW DATA FILE AS OUTPUT BY SUN SYSTEM
        C     INTERPRETS AND STORES DATA FOR SUBSEQUENT PLOTTING
        C
0002          COMMON/BINARY/
             1     NACT,              ! NO. OF ACTIVE CHANNELS
             2     NROS,              ! NO. OF ACTIVE ROSETTES
             3     MSHORT,            ! LENGTH OF THE SHORTEST RECORD
             4     MLONG,             ! LENGTH OF THE LONGEST RECORD
             5     LCH(2),            ! CHANNEL NO. FOR LOAD TYPE 1 & 2
             6     ICHN(3,10),        ! CHANNEL NO. FOR STRAIN TYPE I, ROSETTE J
             7     TITLE(60,4),       ! TITLE INFO FROM RAW DATA FILE
             8     NRD(30),           ! NO. OF READINGS ON CHANNEL I
             9     IROS(30)           ! ROSETTE NO. FOR CHANNEL I (OR LOAD IF < 0)
0003          COMMON/BINARY/
             1     ITYPE(30),         ! STRAIN TYPE FOR CHANNEL I
             2     A(30),B(30),       ! CONVERSION FACTORS FOR STRAIN CHANNELS
             3     TIME(80,30),       ! TIMES FOR READING NO. I ON CHANNEL J
             4     VALUE(80,30)       ! STRAIN READING NO. I ON CHANNEL J
0004          BYTE TITLE
0005          BYTE STUFF(19932)
0006          EQUIVALENCE (STUFF,NACT)
0007          COMMON/MISC/NRUNN,TLD(10,2),TDIR(10,3),JOBTIT(60)
0008          BYTE TLD,TDIR,JOBTIT
0009          LOGICAL WANT,CHECK
0010          COMMON/PLT/NP(30),LYNE(126),LYNE2(126),LYNE3(126)
0011          BYTE LYNE,LYNE2,LYNE3
0012          BYTE BLANK,DOLLAR,X,E,O,R,LINE(20)
0013          DATA BLANK,DOLLAR,E,O,R/' ','$','E','O','R'/
0014          DATA LSTUFF/19932/
0015          DATA IVMAX/2040/
0016          CALL ERASE
0017          CALL BLANKIT(TITLE,4*60)
0018          NTIT=2
0019          READ(1,22,END=30) (TITLE(J,1),J=1,60)
0020          TYPE 1,NRUN
0021    1     FORMAT (' READING RAW DATA FOR RUN NUMBER',I3/
             1     ' TITLE LINES READ FROM FILE:')
0022          AD=0.
0023          BD=0.
0024          CALL CLEAR(NRD,30)
0025          CALL CLEAR(IROS,30)
0026          CALL CLEAR(ITYPE,30)
0027          CALL CLEAR(ICHN,30)
0028          CALL CLEAR(LCH,2)
0029          WRITE(5,41) (TITLE(J,1),J=1,60)
        C
        C     GET TITLE LINES
        C
0030    20    READ(1,22,END=31) (TITLE(J,NTIT),J=1,60)
0031    22    FORMAT (60A1)
        C
        C     FOUND $, END OF TITLE INFO
```

```
      C
0032        IF (TITLE(1,NTIT).NE.DOLLAR) GO TO 40
0034        TITLE(1,NTIT)=BLANK
0035        NTIT=NTIT-1
0036        GO TO 50
      C
      C     HIT ECF
      C
0037  30    RAWDAT=-1.
0038        RETURN
0039  31    CALL DISPLAY(' EOR MISSING ON LAST RUN')
0040        RAWDAT=-1.
0041        RETURN
0042  32    CALL DISPLAY('EOR MISSING ON LAST RUN')
0043        CALL DISPLAY('YOU ARE FORGIVEN')
0044        GO TO 200
      C
      C     GET ANOTHER LINE
      C
0045  40    WRITE(5,41) (TITLE(J,NTIT),J=1,60)
0046        NTIT=NTIT+1
0047        WRITE(5,41) (TITLE(J,NTIT),J=1,60)
0048  41    FORMAT (1X,60A1)
0049        IF (NTIT.LE.4) GO TO 20
0051  45    READ(1,22) X
0052        NTIT=NTIT+1
0053        IF (X.EQ.DOLLAR) GO TO 50
0055        IF (NTIT.GT.10) STOP '$ MISSING AFTER TITLE LINES'
0057        GO TO 45
      C
      C     READ IN RAW DATA AND CHECK FORMAT
      C
0058  50    READ(1,51,END=32) NL,LINE
0059  51    FORMAT (Q,20A1)
0060        IF (LINE(1).NE.E) GO TO 100
0062        IF (LINE(2).NE.O) GO TO 100
0064        IF (LINE(3).NE.R) GO TO 100
      C
      C     END OF RECORD, GO PROCESS IT
      C
0066        GO TO 200
      C
      C     CHECK DATA FORMAT
      C
0067        IF (CHECK(LINE,NL)) GO TO 100
0069  55    WRITE(5,60) (LINE(I),I=1,NL)
0070  60    FORMAT (' FOLLOWING LINE HAS A FORMAT ERROR:'/1X,20A1)
0071        IF (.NOT.WANT('WANT TO DISCARD THIS LINE AND CONTINUE'))
           1     STOP
0073        GO TO 50
      C
      C     DECODE CHANNEL NO., TIME, VALUE
      C
0074  100   DECODE(20,110,LINE) JCHN,IMIN,ISEC,IFRAC,IVALLE
```

```
FORTRAN IV      V02.04          FRI 04-JAN-80 09:47:06          PAGE 003
CORE=31K, UIC=(212,1)                                   ,RAWDAT/EX=RAWDAT

0075  110    FORMAT (1X,I3,1X,3(I2,1X),I5)
0076         IF (JCHN.LE.0.OR.JCHN.GT.30) GO TO 55
      C
      C      CHECK FOR OVERLOAD
      C
0078         IF (IABS(IVALUE).LE.IVMAX) GO TO 130
0080         WRITE(5,120) JCHN
0081  120    FORMAT (' OVERLOAD ON CHANNEL',I3)
0082         GO TO 50
0083  130    NRD(JCHN)=NRD(JCHN)+1
0084         NR=NRD(JCHN)
0085         IF (ISEC.GT.59) GO TO 55
0087         TIME(NR,JCHN)=60.*IMIN+ISEC+.01*IFRAC
0088         VALUE(NR,JCHN)=IVALUE
      C
      C      GO GET ANOTHER LINE
      C
0089         GO TO 50
      C
      C      DONE READING, NOW HAVE TO RUN THRU EACH CHANNEL
      C      AND GET MORE INFO FROM USER
      C
0090  200    MSHORT=30000
0091         MLONG=0
0092         DO 400 JCHN=1,30
0093         NR=NRD(JCHN)
0094         IF (NR.EQ.0) GO TO 400
0096         MSHORT=MIN0(MSHORT,NR)
0097         MLONG=MAX0(MLONG,NR)
0098  205    WRITE(5,210) JCHN
0099  210    FORMAT (' PLEASE IDENTIFY CHANNEL',I3)
0100         N=ISREAD('"S" FOR STRAIN; "L" FOR LOAD; "X" IF UNUSED',X,1,1)
      C
      C      STRAIN CHANNEL
      C
0101         IF (X.NE.'S') GO TO 250
0103         JROS=IREAD('ROSETTE NO.',1,12,'NONE')
0104         WRITE(5,220) TDIR
0105  220    FORMAT (' STRAIN TYPES:'/
            1     '   1=',10A1/
            2     '   2=',10A1/
            3     '   3=',10A1)
0106         JTYPE=IREAD('STRAIN TYPE FOR THIS CHANNEL',1,3,'NONE')
0107         IF (ICHN(JTYPE,JROS).EQ.0) GO TO 240
0109         WRITE(5,230) ICHN(JTYPE,JROS),JROS,(TDIR(J,JTYPE),J=1,10)
0110  230    FORMAT (' CHANNEL',I3,' HAS BEEN IDENTIFIED WITH ROSETTE',I3,
            12X,10A1,' STRAIN!')
0111         GO TO 205
0112  240    ITYPE(JCHN)=JTYPE
0113         IROS(JCHN)=JROS
0114         ICHN(JTYPE,JROS)=JCHN
0115         CALL DISPLAY('ENTER FACTORS A AND B TO CONVERT TO STRAIN UNITS')
0116         CALL DISPLAY('  X=AR+B')
0117         CALL DISPLAY('  WHERE R=RAW DATA, X=STRAIN UNITS')
```

```
      A(JCHN)=RREAD('A','NONE','NONE',AD)
      AD=A(JCHN)
      B(JCHN)=RREAD('B','NONE','NONE',BD)
      BD=B(JCHN)
      GO TO 400
C
C     LOAD CHANNEL
C
250   IF (X.NE.'L') GO TO 300
      WRITE(5,260) TLD
260   FORMAT (' LOAD TYPES:'/
     1    '    1=',10A1/
     2    '    2=',10A1)
      ILD=IREAD('LOAD TYPE FOR THIS CHANNEL',1,2,'NONE')
      IF (LCH(ILD).EQ.0) GO TO 270
      WRITE(5,265) LCH(ILD),(TLD(J,ILD),J=1,10)
265   FORMAT (' CHANNEL',I3,' HAS BEEN IDENTIFIED WITH ',10A1,' LOAD!')
      GO TO 205
270   IROS(JCHN)=-ILD
      LCH(ILD)=JCHN
      CALL DISPLAY('ENTER FACTORS A & B TO CONVERT TO LOAD UNITS')
      CALL DISPLAY('  X=AR+B')
      CALL DISPLAY('  WHERE R=RAW DATA, X=LOAD UNITS')
      A(JCHN)=RREAD('A','NONE','NONE',AD)
      AD=A(JCHN)
      B(JCHN)=RREAD('B','NONE','NONE',BD)
      BD=B(JCHN)
      GO TO 400
C
C     UNUSED CHANNEL
C
300   IF (X.NE.'X') GO TO 205
C
C     NEXT CHANNEL
C
400   CONTINUE
C
C     THAT'S ALL; DUMP IT OUT
C
      WRITE(2) STUFF
      RAWDAT=1.
C
C     PRINT STUFF OUT
C
      IF (.NOT.WANT('WANT TO PRINT OUT RAW DATA')) GO TO 800
      WRITE(3,505) TITLE
505   FORMAT (1H1/(1X,60A1))
      DO 508 I=1,30
508   NP(I)=NRD(I)
510   CALL BLANKIT(LYNE,126*3)
      WRITE(3,511) LYNE
511   FORMAT (1X,126A1)
520   LTAB=0
      DO 610 I=1,30
```

```
FORTRAN IV      V02.04          FRI 04-JAN-80 09:47:06          PAGE 005
CORE=31K, UIC=(212,1)                                  ,RAWDAT/EX=RAWDAT

0159              IF (NP(I).EQ.0) GO TO 610
0161              ENCODE(21,530,LYNE(21*LTAB+1)) I
0162      530     FORMAT (6X,7HCHANNEL,I3,5X)
0163              IF (IROS(I)) 580,560,535
0164      535     ENCODE(21,540,LYNE2(21*LTAB+1)) IROS(I)
0165      540     FORMAT (6X,7HROSETTE,I3,5X)
0166              ENCODE(21,550,LYNE3(21*LTAB+1)) (TDIR(J,ITYPE(I)),J=1,10)
0167      550     FORMAT (2X,10A1,7H STRAIN,2X)
0168              GO TO 600
0169      560     ENCODE(21,570,LYNE2(21*LTAB+1))
0170      570     FORMAT (8X,6HUNUSED,7X)
0171      575     CALL BLANKIT(LYNE3(21*LTAB+1),21)
0172              GO TO 600
0173      580     ENCODE (21,590,LYNE2(21*LTAB+1)) (TLD(J,-IROS(I)),J=1,10)
0174      590     FORMAT (3X,10A1,5H LOAD,3X)
0175              CALL BLANKIT(LYNE3(21*LTAB+1),21)
0176              GO TO 575
0177      600     LTAB=LTAB+1
0178              IF (LTAB.EQ.6) GO TO 620
0180      610     CONTINUE
0181              IF (LTAB.EQ.0) GO TO 800
0183      620     WRITE(3,511) LYNE,LYNE2,LYNE3
0184              DO 625 ITAB=1,LTAB
0185      625     ENCODE(21,626,LYNE(21*(ITAB-1)+1))
0186              WRITE(3,511) LYNE
0187      626     FORMAT (4X,4HTIME,1X,7HREADING,5X)
0188      630     LTAB=0
0189              DO 680 I=1,30
0190              IF (NP(I)) 670,680,640
0191      640     N=NRD(I)-NP(I)+1
0192              IF (N.EQ.0) GO TO 670
0194      650     ENCODE(21,660,LYNE(21*LTAB+1)) TIME(N,I),VALUE(N,I)
0195      660     FORMAT (F8.2,F8.0,5X)
0196              NP(I)=NP(I)-1
0197              IF (NP(I).EQ.0) NP(I)=-1
0199              GO TO 675
0200      670     CALL BLANKIT(LYNE(21*LTAB+1),21)
0201      675     LTAB=LTAB+1
0202              IF (LTAB.EQ.6) GO TO 685
0204      680     CONTINUE
0205      685     WRITE(3,511) LYNE
0206              DO 690 I=1,126
0207              IF (LYNE(I).NE.' ') GO TO 630
0209      690     CONTINUE
0210              L=0
0211              DO 700 I=1,30
0212              IF (NP(I).EQ.-1) NP(I)=0
0214              L=L+NP(I)
0215      700     CONTINUE
0216              IF (L.NE.0) GO TO 510
0218      800     CALL PAUSE
0219              RETURN
0220              END
```

```
FORTRAN IV      V02.04          FRI 04-JAN-80 09:47:35          PAGE 001
CORE=31K, UIC=(212,1)                                   ,CHECK/EX=CHECK

      LOGICAL FUNCTION CHECK(LINE,N)
      BYTE LINE(20)
      LOGICAL NUM
      BYTE SHOULD(13),CHAR,ZERO,NINE
      DATA SHOULD/2,3,4,6,7,9,10,12,13,16,17,18,19/
      DATA ZERO,NINE/'0','9'/
      NUM(CHAR)=CHAR.GE.ZERO.AND.CHAR.LE.NINE
      CHECK=N.GE.19
      DO 10 I=1,13
10    CHECK=CHECK.AND.NUM(LINE(SHOULD(I)))
      RETURN
      END
```

```
FORTRAN IV      V02.04          FRI 04-JAN-80 09:47:24          PAGE 001
CORE=31K, UIC=(212,1)                                  ,REVIEW/EX=REVIEW

0001          SUBROUTINE REVIEW
0002          COMMON/MISC/NRUN,TLD(10,2),TDIR(10,3),JOBTIT(60)
0003          BYTE TLD,TDIR,JOBTIT
0004          COMMON/BINARY/NACT,NROS,MSHORT,MLONG,
             1    LCH(2),ICHN(3,10),TITLE(60,4),NRD(30),IROS(30),
             2    ITYPE(30),A(30),B(30),
             3    TIME(80,30),VALUE(80,30)
0005          BYTE TITLE
0006          LOGICAL WANT
0007          DATA VMAX/2040./
0008          IF (.NOT.WANT('WANT TO REVIEW RUNS ON FILE')) RETURN
0010          CALL ERASE
0011          DO 100 IRUN=1,NRUN
0012          CALL GETDAT(IRUN)
0013          WRITE(5,10) IRUN,TITLE
0014    10    FORMAT (' RUN',I3/(4X,60A1))
0015          DO 50 ICH=1,30
0016          NR=NRD(ICH)
0017          IF (NR.EQ.0) GO TO 50
0019          DO 12 J=1,NR
0020          IF (ABS(VALUE(J,ICH)).GT.VMAX) GO TO 15
0022    12    CONTINUE
0023          J=NR
0024    15    NRD(ICH)=J
0025          IF (IROS(ICH)) 40,50,20
0026    20    WRITE(5,30) A(ICH),B(ICH),ICH,IROS(ICH),(TDIR(J,ITYPE(ICH)),J=1,10)
0027    30    FORMAT (T50,'A=',E10.4,5X,'B=',E10.4,T1,'  CHANNEL',I3,':',
             1    '  ROSETTE NO.',I3,2X,10A1)
0028          GO TO 50
0029    40       WRITE(5,45) A(ICH),B(ICH),ICH,(TLD(J,-IROS(ICH)),J=1,10)
0030    45    FORMAT (T50,'A=',E10.4,5X,'B=',E10.4,T1,'  CHANNEL',I3,':',
             1    '  ',10A1,' LOAD')
0031    50    CONTINUE
0032   100    CALL PAUSE
0033          RETURN
0034          END
```

```
FORTRAN IV      V02.04          FRI 04-JAN-80 09:47:47          PAGE 001
CORE=31K, UIC=(212,1)                                     ,GETDAT/EX=GETDAT

0001          SUBROUTINE GETDAT(IR)
        C
        C     READS IN DATA FOR ONE RUN INTO COMMON BLOCK "BINARY"
        C     EXCEPT IF IRUN=0, READS INTO BLOCK "MISC" FROM LAST REC
        C
0002          COMMON/MISC/NRUN,TLD(10,2),TDIR(10,3),JOBTIT(60)
0003          BYTE TLD,TDIR,JOBTIT
0004          COMMON/BINARY/STUFF(19932)
0005          BYTE STUFF
0006          DATA IPOS/-10/
0007          IRUN=IABS(IR)
0008          IF (IRUN.NE.0) GO TO 30
0010    10    READ(2,END=20)
0011          GO TO 10
0012    20    BACKSPACE 2
0013          READ(2) NRUN,TLD,TDIR,JOBTIT
0014          REWIND 2
0015          IPOS=1
0016          RETURN
0017    30    IF (IRUN.LT.0.OR.IRUN.GT.NRUN)
             1     STOP 'BAD CALL TO GETDAT'
0019          IF (IPOS.EQ.-10) GO TO 80
0021          IF (IPOS.EQ.IRUN+1.AND.IR.GT.0) RETURN
0023          IF (IR.EQ.1.AND.NRUN.EQ.1) RETURN
0025          IF (IPOS-IRUN) 40,70,80
0026    40    NSKIP=IRUN-IPOS
0027    50    DO 60 I=1,NSKIP
0028    60    READ(2)
0029    70    READ(2) STUFF
0030          IPOS=IRUN+1
0031          IF (IRUN.LT.NRUN) RETURN
0033          REWIND 2
0034          IPOS=1
0035          RETURN
0036    80    REWIND 2
0037          IPOS=1
0038          NSKIP=IRUN-1
0039          IF (NSKIP.GT.0) GO TO 50
0041          GO TO 70
0042          END
```

```
FORTRAN IV      V02.04          FRI 04-JAN-80 09:47:57          PAGE 001
CORE=31K, UIC=(212,1)                             ,BLANKIT/EX=BLANKIT

      SUBROUTINE BLANKIT(LINE,N)
      BYTE LINE(1)
      DO 1 I=1,N
1     LINE(I)=' '
      RETURN
      END
```

```
FORTRAN IV      V02.04          FRI 04-JAN-80 09:48:16          PAGE 001
CORE=31K, UIC=(212,1)                                   ,PLTGEN/EX=PLTGEN

0001            SUBROUTINE PLTGEN
          C
          C     GENERATES DATA FOR ONE GRAPH CONSISTING OF SEVERAL CURVES
          C     PER USER SPECIFICATION
          C
          C     CALL TO GETDAT FILLS COMMON BLOCK "BINARY"
          C     WITH RAW DATA FOR SPECIFIED RUN
          C
0002            COMMON/MISC/NRUN,TLD(10,2),IDIR(10,3),JOBTIT(60)
0003            BYTE TLD,IDIR,JOBTIT
0004            COMMON/CONTROL/REPEAT,JPLT(2)
0005            LOGICAL REPEAT
0006            COMMON/BINARY/NACT,NROS,MSHORT,MLONG,
               1    LCH(2),ICHN(3,10),TITLE(60,4),NRD(30),IRGS(30),
               2    ITYPE(30),A(30),B(30),
               3    TIME(80,30),VALUE(80,30)
0007            BYTE TITLE
0008            COMMON/PLT/NCURVE,
               1    XMAX,XMIN,YMAX,YMIN,XSC,YSC,XL,YL,
               2    XY(70,2,8),              ! DATA POINT I, X OR Y, CURVE J
               3    XYT(70,8),               ! TIME FOR POINT I, CURVE J
               4    NXY(8),                  ! NO. OF DATA POINTS, CURVE I
               5    NLAB(2),LABEL(40,2),     ! LABELS & LENGTHS OF LABELS FOR X & Y
               6    NPTIT,PLTIT(60),         ! PLOT TITLE & LENGTH
               7    LEGEND(40,8)             ! LEGEND LINE FOR EACH CURVE
0009            BYTE LABEL,PLTIT,LEGEND
0010            BYTE AX,TYPE,SHEAR(10)
0011            COMMON/SLD/SL(3,2,2)         ! FACTORS TO CALC STRESS FROM LOAD
          C                                    I=1,2,3 STRESS TYPE
          C                                    J=AXIS
          C                                    K=LOAD1, LOAD2
0012            DIMENSION JCH(3),S(3),T(3)
0013            LOGICAL WANT
0014            BYTE ABC
0015            ABC(1)="100+1
0016            DATA OVER/'OVER'/
          C
          C     GET USER SPECS FOR X & Y AXES
          C
0017            ENCODE(10,5,SHEAR)
0018      5     FORMAT(10HMAX SHEAR )
0019            CALL ERASE
0020            CALL DISPLAY(' PREPARING TO PLOT:')
0021            CALL GETDAT(-1)
0022            AX='X'
0023            DO 100 JAX=1,2
0024            WRITE(5,10) AX
0025      10    FORMAT (' THE FOLLOWING INFORMATION IS REQUESTED FOR THE ',
               1    A1,' AXIS:')
0026            IF (.NOT.REPEAT) GO TO 12
0028            IF (WANT('WANT THE SAME INFO FOR THIS AXIS AS FOR PREVIOUS PLOT'))
               1 GO TO 100
0030      12    N=ISREAD('"S" TO PLOT A STRAIN ON THIS AXIS; "T" TO PLOT A STRESS',
               1    TYPE,1,1)
```

```
FORTRAN IV      V02.04          FRI 04-JAN-80 09:48:16              PAGE 002
CORE=31K, UIC=(212,1)                                         ,PLTGEN/EX=PLTGEN

0031            IF (TYPE.NE.'S') GO TO 35
          C
          C     PLOT A STRAIN
          C
0033            IF (WANT('WANT TO PLOT A PRINCIPAL STRAIN')) GO TO 30
          C
          C     NOT A PRINCIPAL STRAIN
          C
0035            WRITE(5,20) TDIR
0036      20    FORMAT(' STRAIN TYPES:'/
               1     '    1=',10A1/
               2     '    2=',10A1/
               3     '    3=',10A1)
0037            JPLT(JAX)=IREAD('STRAIN KEY',1,3,'NONE')
0038            GO TO 90
          C
          C     PRINCIPAL STRAIN
          C
0039      30    CALL DISPLAY('PRINCIPAL STRAIN KEY:')
0040            CALL DISPLAY('   1=MAJOR PRINCIPAL')
0041            CALL DISPLAY('   2=MINOR PRINCIPAL')
0042            CALL DISPLAY('   3=MAX SHEAR')
0043            JPLT(JAX)=3+IREAD('PRINCIPAL STRAIN KEY',1,3,'NONE')
0044            GO TO 90
          C
          C     PLOT A STRESS
          C
0045      35    IF (TYPE.NE.'T') GO TO 12
0047            WRITE(5,40) ((TDIR(J,1),J=1,10),TLD,JJ=1,2)
0048      40    FORMAT (' ENTER FACTORS A & B REQUIRED TO CALCULATE ',10A1,
               1     ' STRESS'/' FROM ',10A1,' AND ',10A1,' LOADS'/
               2     ' WHERE:'/
               3     '    S=A*L1 + B*L2'/
               4     '    S=',10A1,' STRESS'/
               5     '    L1=',10A1,' LOAD'/
               6     '    L2=',10A1,' LOAD')
0049            SL(1,JAX,1)=RREAD('A','NONE','NONE',SL(1,JAX,1))
0050            SL(1,JAX,2)=RREAD('B','NONE','NONE',SL(1,JAX,2))
0051            WRITE(5,40) ((TDIR(J,2),J=1,10),TL2)
0052            SL(2,JAX,1)=RREAD('A','NONE','NONE',SL(2,JAX,1))
0053            SL(2,JAX,2)=RREAD('B','NONE','NONE',SL(2,JAX,2))
0054            WRITE(5,40) (SHEAR,TLD,JJ=1,2)
0055            SL(3,JAX,1)=RREAD('A','NONE','NONE',SL(3,JAX,1))
0056            SL(3,JAX,2)=RREAD('B','NONE','NONE',SL(3,JAX,2))
0057            IF (WANT('WANT A PRINCIPAL STRESS')) GO TO 60
          C
          C     NOT PRINCIPAL STRESS
          C
0059            WRITE(5,50) ((TDIR(J,K),J=1,10),K=1,2),SHEAR
0060      50    FORMAT (' STRESS KEY:'/
               1     '   1=',10A1/
               2     '   2=',10A1/
               3     '   3=',10A1)
0061            JPLT(JAX)=-IREAD('STRESS KEY',1,3,'NONE')
```

```
        GO TO 90
C
C       PRINCIPAL STRESS
C
  60    CALL DISPLAY('PRINCIPAL STRESS KEY:')
        CALL DISPLAY('  1=MAJOR PRINCIPAL')
        CALL DISPLAY('  2=MINOR PRINCIPAL')
        CALL DISPLAY('  3=MAX SHEAR')
        JPLT(JAX)=-3-IREAD('PRINCIPAL STRESS KEY',1,3,'NONE')
C
C       GET LABEL FOR THIS AXIS
C
  90    CALL BLANKIT(LABEL(1,JAX),40)
        NLAB(JAX)=ISREAD('LABEL FOR THIS AXIS',LABEL(1,JAX),1,40)
C
C       REPEAT FOR Y AXIS
C
 100    AX='Y'
C
C       GET TITLE FOR THE WHOLE PLOT
        CALL BLANKIT(PLTIT,60)
C
        NPTIT=ISREAD('TITLE FOR THE WHOLE PLOT',PLTIT,1,60)
C
C       ASK WHAT DATA TO PLOT
C
        CALL DISPLAY('YOU MAY NOW SPECIFY UP TO 8 CURVES')
        CALL DISPLAY(' TO BE DRAWN ON ONE PLOT')
        CALL REVIEW
        IRUN=1
        XMAX=0.
        XMIN=1.E6
        YMAX=0.
        YMIN=1.E6
        DO 600 ICURVE=1,8
 105    WRITE(5,110) ABC(ICURVE)
 110    FORMAT (' FOR CURVE ',A1,':')
        IR=1
        IF (NRUN.GT.1) IR=IREAD('RUN NO.',1,NRUN,IRUN)
        CALL GETDAT(IR)
C
C       DO X-AXIS
C
        JPL=JPLT(1)
        IF (JPL.LE.0) GO TO 180
C
C       STRAIN PLOTTED: GET DATA
C
 120    JROS=IREAD('ROSETTE NO. FOR X AXIS',1,8,'NONE')
        IF (JPL.GT.3) GO TO 160
C
C       NOT PRINCIPAL STRAIN
C
        ICH=ICHN(JPL,JROS)
```

```
0095          NR=NRD(ICH)
0096          IF (NR.GT.0) GO TO 140
0098          WRITE(5,130) (TDIR(J,JPL),J=1,10),JROS,IRUN
0099    130   FORMAT (1X,10A1,' STRAIN NOT RECORDED FOR ROSETTE NO.',I3,', RUN NO.',I3)
0100          GO TO 120
0101    140   DO 150 I=1,NR
0102          XY(I,1,ICURVE)=VALUE(I,ICH)*A(ICH)+B(ICH)
0103    150   XYT(I,ICURVE)=TIME(I,ICH)
0104          GO TO 300
        C
        C     PRINCIPAL STRAIN
        C
0105    160   DO 170 J=1,3
0106          JCH(J)=ICHN(J,JROS)
0107          IF (JCH(J).GT.0) GO TO 170
0109          WRITE(5,130) (TDIR(K,J),K=1,10),JROS,IRUN
0110          GO TO 105
0111    170   CONTINUE
0112          NR=NRD(JCH(1))
0113          NXY(ICURVE)=NR
0114          DO 175 I=1,NR
0115          S(1)=VALUE(I,JCH(1))*A(JCH(1))+B(JCH(1))
0116          S(2)=XTERP(VALUE(1,JCH(2)),TIME(1,JCH(2)),TIME(I,JCH(1)),NRD(JCH(2)))
0117          IF (S(2).EQ.OVER) GO TO 176
0119          S(3)=XTERP(VALUE(1,JCH(3)),TIME(1,JCH(3)),TIME(I,JCH(1)),NRD(JCH(3)))
0120          IF (S(3).EQ.OVER) GO TO 176
0122          CALL PRINC(S,T,ANG)
0123          XY(I,1,ICURVE)=T(JPL-3)
0124    175   XYT(I,ICURVE)=TIME(I,JCH(1))
0125          GO TO 300
0126    176   NXY(ICURVE)=I-1
0127          GO TO 300
        C
        C     STRESS ON X AXIS
        C
0128    180   JPL=-JPL
0129          IF (JPL.GT.3) GO TO 220
        C
        C     NOT A PRINCIPAL STRESS
        C
0131          LD=1
0132          IF (NRD(LCH(2)).GT.NRD(LCH(1))) LD=2
0134          DO 200 LLD=1,2
0135          IF (SL(JPL,1,LLD).EQ.0..OR.NRD(LCH(LLD)).NE.0) GO TO 200
0137          WRITE(5,190) (TLD(J,LLD),J=1,10),IRUN
0138    190   FORMAT (' NO DATA FOR ',10A1,' LOAD FOR RUN',I2)
0139          GO TO 105
0140    200   CONTINUE
0141          NR=NRD(LCH(LD))
0142          NXY(ICURVE)=NR
0143          LCH1=LCH(3-LD)
0144          LCH2=LCH(LD)
0145          DO 210 I=1,NR
0146          XLD1=A(LCH1)*VALUE(I,LCH1)+B(LCH1)
```

```
      XLD2=XTERP(VALUE(1,LCH2),TIME(1,LCH2),TIME(1,LCH1),NRD(LCH2))
      IF (XLD2.EQ.OVER) GO TO 211
      XLD2=A(LCH2)*XLD2+B(LCH2)
      XY(I,1,ICURVE)=SL(JPL,1,3-LD)*XLD1+SL(JPL,1,LD)*XLD2
210   XYT(I,ICURVE)=TIME(1,LCH2)
      GO TO 300
211   NXY(ICURVE)=I-1
      GO TO 300
C
C     PRINCIPAL STRESS
C
220   DO 240 LLD=1,2
      IF (NRD(LCH(LLD)).NE.0) GO TO 240
      WRITE(5,190) (TLD(J,LLD),J=1,10),IRUN
      GO TO 105
240   CONTINUE
      LD=1
      IF (NRD(LCH(2)).GT.NRD(LCH(1))) LD=2
      NR=NRD(LCH(LD))
      NXY(ICURVE)=NR
      LCH1=LCH(3-LD)
      LCH2=LCH(LD)
      DO 260 I=1,NR
      XLD1=A(LCH1)*VALUE(I,LCH1)+B(LCH1)
      XLD2=XTERP(VALUE(1,LCH2),TIME(1,LCH2),TIME(I,LCH1),NRD(LCH2))
      IF (XLD2.EQ.OVER) GO TO 261
      XLD2=A(LCH2)*XLD2+B(LCH2)
      DO 250 J=1,3
250   S(J)=SL(J,1,3-LD)*XLD1+SL(J,1,LD)*XLD2
      CALL PRINC(S,T,ANG)
260   XY(I,1,ICURVE)=T(JPL-3)
      GO TO 300
261   NXY(ICURVE)=I-1
      GO TO 300
C
C     Y AXIS
C
300   JPL=JPLT(2)
      IF (JPL.LE.0) GO TO 380
C
C     STRAIN PLOTTED; GET DATA
C
320   JROS=IREAD('ROSETTE NO. FOR Y AXIS',1,8,'NONE')
      IF (JPL.GT.3) GO TO 360
C
C     NOT PRINCIPAL STRAIN
C
      ICH=ICHN(JPL,JROS)
      NR=NXY(ICURVE)
      IF (NRD(ICH).GT.0) GO TO 340
      WRITE(5,130) (TDIR(J,JPL),J=1,10),JROS,IRUN
      GO TO 320
340   DO 350 I=1,NR
      XT=XTERP(VALUE(1,ICH),TIME(1,ICH),XYT(I,ICURVE),NRD(ICH))
```

```
0196           IF (XT.EQ.OVER) GO TO 351
0198     350   XY(I,2,ICURVE)=A(ICH)*XT+B(ICH)
0199           GO TO 500
0200     351   NXY(ICURVE)=I-1
0201           GO TO 500
           C
           C   PRINCIPAL STRAIN
           C
0202     360   DO 370 J=1,3
0203           JCH(J)=ICHN(J,JROS)
0204           IF (JCH(J).GT.0) GO TO 370
0206           WRITE(5,130) (TDIR(K,J),K=1,10),JROS,IRUN
0207           GO TO 105
0208     370   CONTINUE
0209           NR=NXY(ICURVE)
0210           DO 375 I=1,NR
0211           DO 372 J=1,3
0212           S(J)=XTERP(VALUE(1,JCH(J)),TIME(1,JCH(J)),XYT(I,ICURVE),NRD(JCH(J)))
0213           IF (S(J).EQ.OVER) GO TO 376
0215     372   CONTINUE
0216           CALL PRINC(S,T,ANG)
0217     375   XY(I,2,ICURVE)=T(JPL-3)
0218           GO TO 500
0219     376   NXY(ICURVE)=I-1
0220           GO TO 500
           C
           C   STRESS ON Y AXIS
           C
0221     380   JPL=-JPL
0222           IF (JPL.GT.3) GO TO 430
           C
           C   NOT A PRINCIPAL STRESS
           C
0224           DO 400 LLD=1,2
0225           IF (SL(JPL,2,LD).EQ.0..OR.NRD(LCH(LLD)).NE.0) GO TO 400
0227           WRITE(5,190) (TLD(J,LLD),J=1,10),IRUN
0228           GO TO 105
0229     400   CONTINUE
0230           NR=NXY(ICURVE)
0231           LCH1=LCH(1)
0232           LCH2=LCH(2)
0233           DO 410 I=1,NR
0234           XLD1=XTERP(VALUE(1,LCH1),TIME(1,LCH1),XYT(I,ICURVE),NRD(LCH1))
0235           IF (XLD1.EQ.OVER) GO TO 411
0237           XLD1=A(LCH1)*XLD1+B(LCH1)
0238           XLD2=XTERP(VALUE(1,LCH2),TIME(1,LCH2),XYT(I,ICURVE),NRD(LCH2))
0239           IF (XLD2.EQ.OVER) GO TO 411
0241     410   XY(I,2,ICURVE)=SL(JPL,2,1)*XLD1+SL(JPL,2,2)*XLD2
0242           GO TO 500
0243     411   NXY(ICURVE)=I-1
0244           GO TO 500
           C
           C   PRINCIPAL STRESS
           C
```

```
0245  430   DO 440 LLD=1,2
0246        IF (NRD(LCH(LLD)).NE.0) GO TO 430
0248        WRITE(5,190) (TLD(J,LLD),J=1,10),IRUN
0249        GO TO 105
0250  440   CONTINUE
0251        NR=NXY(ICURVE)
0252        LCH1=LCH(1)
0253        LCH2=LCH(2)
0254        DO 460 I=1,NR
0255        XLD1=XTERP(VALUE(1,LCH1),TIME(1,LCH1),XYT(1,ICURVE),NRD(LCH1))
0256        IF (XLD1.EQ.OVER) GO TO 461
0258        XLD1=A(LCH1)*XLD1+B(LCH1)
0259        XLD2=XTERP(VALUE(1,LCH2),TIME(1,LCH2),XYT(1,ICURVE),NRD(LCH2))
0260        IF (XLD2.EQ.OVER) GO TO 461
0262        XLD2=A(LCH2)*XLD2+B(LCH2)
0263        DO 450 J=1,3
0264  450   S(J)=SL(J,2,3-LD)*XLD1+SL(J,2,LD)*XLD2
0265        CALL PRINC(S,1,ANG)
0266  460   XY(I,2,ICURVE)=T(JPL-3)
0267        GO TO 500
0268  461   NXY(ICURVE)=I-1
0269        GO TO 500
0270  500   DO 510 I=1,NXY(ICURVE)
0271        XMAX=AMAX1(XMAX,XY(I,1,ICURVE))
0272        XMIN=AMIN1(XMIN,XY(I,1,ICURVE))
0273        YMAX=AMAX1(YMAX,XY(I,2,ICURVE))
0274  510   YMIN=AMIN1(YMIN,XY(I,2,ICURVE))
0275        IF (NRUN.GT.1) WRITE(5,520) TITLE
0277  520   FORMAT (' TITLE INFO FROM SUN FILE:'/(1X,60A1))
0278        CALL BLANKIT(LEGEND(1,ICURVE),40)
0279        NLEG=ISREAD('A SUMMARY TITLE FOR THIS CURVE',
          1     LEGEND(1,ICURVE),1,40)
0280        IF (.NOT.WANT('WANT ANY MORE CURVES ON THIS PLOT')) GO TO 700
0282  600   CONTINUE
0283  700   NCURVE=ICURVE
0284        REPEAT=.TRUE.
0285        RETURN
0286        END
```

```
FORTRAN IV      V02.04          FRI 04-JAN-80 09:48:42          PAGE 001
CORE=31K, UIC=(212,1)                                           ,XTERP/EX=XTERP

0001            FUNCTION XTERP(VALUE,TIME,T,N)
0002            DIMENSION VALUE(1),TIME(1)
0003            DATA OVER/'OVER'/
        D       WRITE(3,76) (TIME(I),VALUE(I),I=1,N)
        D76     FORMAT (F7.2,F8.2,2X)
0004            IF (T.GT.TIME(1)) GO TO 10
0006            XTERP=VALUE(1)
0007            GO TO 30
0008    10      DO 15 I=1,N
0009            IF (T.GE.TIME(I).AND.T.LT.TIME(I+1)) GO TO 20
0011    15      CONTINUE
0012            XTERP=OVER
0013            GO TO 30
0014    20      S=(VALUE(I+1)-VALUE(I))/(TIME(I+1)-TIME(I))
0015            XTERP=VALUE(I)+S*(T-TIME(I))
0016    30      CONTINUE
        D       WRITE(3,77) T,XTERP
        D77     FORMAT (' XTERP',F7.2,F10.2)
0017            RETURN
0018            END
```

```
FORTRAN IV      V02.04          FRI 04-JAN-80 09:48:58          PAGE 001
CORE=31K, UIC=(212,1)                                  ,SCALE/EX=SCALE

0001            FUNCTION SCALE(X)
0002            DIMENSION XLIM(10)
0003            DATA XLIM/1.,1.25,1.5,2.0,2.5,3.0,4.0,5.0,7.5,10.0/
0004            SCALE=0.0
0005            IF(X.EQ.0.0) RETURN
0007            I=ALOG10(ABS(X))
0008            Y=ABS(X)*10.0**(-I)
0009            DO 10 J=1,10
0010            IF(Y.LE.XLIM(J)) GO TO 20
0012      10    CONTINUE
0013            STOP 'SCALE ERROR'
0014      20    SCALE=SIGN(XLIM(J)*10.0**I,X)
0015            RETURN
0016            END
```

```
FORTRAN IV      V02.04          FRI 04-JAN-80 09:49:08                 PAGE 001
CORE=31K, UIC=(212,1)                                             ,PRINC/EX=PRINC

0001          SUBROUTINE PRINC(S,T,ANG)
0002          DIMENSION S(3),T(3)
        C
        C     S(1) S(2)=NORMAL STRAINS
        C     S(3)=45 DEGREE STRAIN
        C     T(1),T(2)=PRINCIPAL STRAINS
        C     T(3)=MAX SHEAR
        C
0003          A=(S(1)+S(2))/2.
0004          B=((S(1)-S(3))**2+(S(3)-S(2))**2)/2.
0005          B=SQRT(B)
0006          SUM=A+B
0007          DIFF=A-B
0008          IF (ABS(DIFF).GT.ABS(SUM)) GO TO 10
0010          T(1)=SUM
0011          T(2)=DIFF
0012          GO TO 20
0013    10    T(1)=DIFF
0014          T(2)=SUM
0015    20    T(3)=ABS(T(1)-T(2))
0016          RETURN
0017          END
```

```
FORTRAN IV      V02.04          FRI 04-JAN-80 09:49:45              PAGE 001
CORE=31K, UIC=(212,1)                                    ,CURFIT/EX=CURFIT

0001            SUBROUTINE CURFIT
          C
          C     DRAW LEAST SQUARES CURVE FIT THRU DATA
          C     GENERATED BY PLTGEN AND PLOTTED
          C     INDIVIDUALLY BY PLOTIT
          C
0002            COMMON/MISC/NRUN,TLD(10,2),TDIR(10,3),JOBTIT(60)
0003            BYTE TLD,TDIR,JOBTIT
0004            COMMON/PLT/NCURVE,XMAX,XMIN,YMAX,YMIN,XSC,YSC,XL,YL,
               1    XY(70,2,8),XY1(70,8),NXY(8),
               2    NLAB(2),LABEL(40,2),NPTIT,PLTIT(60),
               3    LEGEND(40,8)
0005            BYTE LABEL,PLTIT,LEGEND
0006            COMMON/BINARY/X(400),Y(400),Z(400)
0007            BYTE SYMB
0008            CALL PLOTS
0009            CALL PLOT(0.,0.,-3)
0010            CALL PLOT(2.,2.,-3)
0011            CALL AXIS(0.,0.,LABEL(1,1),-NLAB(1),XL,0.,0.,ABS(XSC/XL))
0012            CALL AXIS(0.,0.,LABEL(1,2),NLAB(2),YL,90.,0.,ABS(YSC/YL))
0013            CALL GRID(0.,0.,16.,10.,0.)
0014            CALL SYMBOL(10.,12.5,,'LEGEND',,6)
0015            SYMB='A'
0016            DO 20 ICURVE=1,NCURVE
0017            CALL SG13(XY(1,2,ICURVE),XY(1,1,ICURVE),Z,NXY(ICURVE),IER)
0018            Z(NXY(ICURVE)+1)=0.
0019            Z(NXY(ICURVE)+2)=ABS(XSC/XL)
0020            CALL LINE(Z,XY(1,2,ICURVE),NXY(ICURVE),1,1,ICURVE)
0021            CALL SYMBOL(10.,12.5-.4*ICURVE,,SYMB,,1)
0022            CALL SYMBOL(10.5,12.5-.4*ICURVE,,LEGEND(1,ICURVE),,40)
0023      20    SYMB=SYMB+1
0024            CALL SYMBOL(0.,12.5,,JOBTIT,,60)
0025            CALL SYMBOL(0.,12.0,,PLTIT,,NPTIT)
0026            CALL SYMBOL(0.,11.5,,'LEAST SQUARES FIT',,17)
0027            CALL PLOT(,,999)
0028            RETURN
0029            END
```

```
0001          SUBROUTINE PLOTIT
        C
        C     PLOTS DATA GENERATED BY PLGEN
        C
0002          COMMON/MISC/NRUN,TLD(10,2),TDIR(10,3),JOBTIT(60)
0003          BYTE TLD,TDIR,JOBTIT
0004          COMMON/PLT/NCURVE,XMAX,XMIN,YMAX,YMIN,XSC,YSC,XL,YL,
             1    XY(70,2,8),XYT(70,8),NXY(8),
             2    NLAB(2),LABEL(40,2),NPTIT,PLTIT(60),
             3    LEGEND(40,8)
0005          COMMON/BINARY/LYNE(128),LYNE2(128),DAT(9),TIM(8)
0006          BYTE LYNE,LYNE2,DAT,TIM
0007          BYTE LABEL,PLTIT,LEGEND
0008          BYTE SYMB,ABC
0009          LOGICAL WANT
0010          ABC(I)="100+I
        C
        C     GET SCALE
        C
0011          IF (XMIN.LT.-XMAX) GO TO 20
0013          XSC=SCALE(XMAX)
0014          XL=16.
0015          WRITE(5,10) 'X'
0016    10    FORMAT (' POSITIVE VALUES ON ',A1,' AXIS')
0017          GO TO 40
0018    20    XSC=SCALE(-XMIN)
0019          XL=-16.
0020          WRITE(5,30) 'X'
0021    30    FORMAT (' NEGATIVE VALUES ON ',A1,' AXIS')
0022    40    WRITE(5,41) 'X',XSC
0023    41    FORMAT (1X,A1,' AXIS WILL RANGE FROM 0.0 TO',E10.3/
             1    '  WHICH YOU MAY NOW OVERRIDE IF YOU WISH.')
0024          XSC=RREAD('X AXIS RANGE',0,0,'NONE',XSC)
0025          IF (YMIN.LT.-YMAX) GO TO 50
0027          YSC=SCALE(YMAX)
0028          YL=10.
0029          WRITE(5,10) 'Y'
0030          GO TO 60
0031    50    YSC=SCALE(-YMIN)
0032          YL=-10.
0033          WRITE(5,30) 'Y'
0034    60    WRITE(5,41) 'Y',YSC
0035          YSC=RREAD('Y AXIS RANGE',0,0,'NONE',YSC)
        C
        C     PRINT STUFF
        C
0036          IF (.NOT.WANT('WANT TO PRINT PLOTTED DATA')) GO TO 200
0038          CALL DATE(DAT)
0039          CALL TIME(TIM)
0040          WRITE(3,100) JOBTIT,DAT,TIM,PLTIT
0041    100   FORMAT (1H1,60A1,40X,9A1,2X,8A1/1X,60A1)
0042          WRITE(3,103) LABEL
0043    103   FORMAT (1H0,5X,'X=',40A1/6X,'Y=',40A1)
0044          ICURVE=0
```

```
        IC2=MINO(NCURVE,4)
  102   CALL BLANKIT(LYNE,2*128)
        WRITE(3,101) LYNE
  101   FORMAT (1X,128A1)
        JCURVE=ICURVE
        DO 130 I=1,IC2
        ICURVE=ICURVE+1
        WRITE(3,110) ABC(ICURVE),(LEGEND(J,ICURVE),J=1,40)
  110   FORMAT (' CURVE',1X,A1,': ',40A1)
        ENCODE(30,120,LYNE(30*I-29)) ABC(ICURVE)
  120   FORMAT (11X,5HCURVE,1X,A1,11X)
  130   ENCODE(30,140,LYNE2(30*I-29))
  140   FORMAT (11X,1HX,11X,1HY,6X)
        WRITE(3,101)
        WRITE(3,101) LYNE,LYNE2
        DO 180 L=1,10000
        ICURVE=JCURVE
        DO 160 I=1,IC2
        CALL BLANKIT(LYNE(30*(I-1)+1),30)
        ICURVE=ICURVE+1
        IF (L.LE.NXY(ICURVE))
     1     ENCODE (30,150,LYNE(30*I-29)) XY(L,1,ICURVE),XY(L,2,ICURVE)
  150   FORMAT (E15.5,E12.5,3X)
  160   CONTINUE
        WRITE(3,101) LYNE
        DO 170 I=1,128
        IF (LYNE(I).NE.' ') GO TO 180
  170   CONTINUE
        GO TO 190
  180   CONTINUE
  190   IC2=MINO(NCURVE-ICURVE,4)
        IF (ICURVE.LT.NCURVE) GO TO 102
C
C       HERE GOES
C
  200   CALL DISPLAY('READY TO PLOT.')
        CALL PAUSE
        CALL PLOTS
        CALL PLOT(2.,2.,-3)
        CALL AXIS(0.,0.,LABEL(1,1),-NLAB(1),XL,0.0,0.0,ABS(XSC/XL))
        CALL AXIS(0.,0.,LABEL(1,2),NLAB(2),YL,90.0,0.0,ABS(YSC/YL))
        CALL GRID(0.,0.,16.,10.,0.)
        DO 710 ICURVE=1,NCURVE
        DO 500 J=1,NXY(ICURVE)
        IF (XL.LT.0.0) XY(J,1,ICURVE)=-XY(J,1,ICURVE)
        IF (YL.LT.0.0) XY(J,2,ICURVE)=-XY(J,2,ICURVE)
        XY(J,1,ICURVE)=AMAX1(0.0,XY(J,1,ICURVE))
  500   CONTINUE
        XY(NXY(ICURVE)+1,1,ICURVE)=0.0
        XY(NXY(ICURVE)+2,1,ICURVE)=ABS(XSC/XL)
        XY(NXY(ICURVE)+1,2,ICURVE)=0.0
        XY(NXY(ICURVE)+2,2,ICURVE)=ABS(YSC/YL)
  710   CALL LINE(XY(1,1,ICURVE),XY(1,2,ICURVE),NXY(ICURVE),1,1,ICURVE)
        CALL SYMBOL(0.,12.5,,JOBTIT,,60)
```

```
FORTRAN IV      V02.04          FRI 04-JAN-80 09:50:01           PAGE 003
CORE=31K, UIC=(212,1)                                    ,PLOT11/EX=PLOT11

          CALL SYMBOL(0.,12.0,,PLTIT,,NPTIT)
          CALL SYMBOL(10.,12.5,,'LEGEND',,6)
          SYMB='A'
          DO 810 ICURVE=1,NCURVE
          CALL SYMBOL(10.,12.5-.4*ICURVE,,SYMB,,1)
          SYMB=SYMB+1
    810   CALL SYMBOL(10.5,12.5-.4*ICURVE,,LEGEND(1,ICURVE),,40)
          CALL PLOT(,,999)
          RETURN
          END
```

```
FORTRAN IV      V02.04          FRI 04-JAN-80 09:50:21         PAGE 001
CORE=31K, UIC=(212,1)                                        ,SG13/LX=SG13

0001          SUBROUTINE SG13(X,Y,Z,NDIM,IER)
        C
        C   LEAST SQUARES ROUTINE
        C
0002          DIMENSION X(NDIM),Y(NDIM),Z(NDIM)
0003          IF(NDIM-3)7,1,1
0004    1     DO 6 I=3,NDIM
0005          XM=.33333333*(X(I-2)+X(I-1)+X(I))
0006          YM=.33333333*(Y(I-2)+Y(I-1)+Y(I))
0007          T1=X(I-2)-XM
0008          T2=X(I-1)-XM
0009          T3=X(I)-XM
0010          XM=T1*T1+T2*T2+T3*T3
0011          IF(XM)3,3,2
0012    2     XM=(T1*(Y(I-2)-YM)+T2*(Y(I-1)-YM)+T3*(Y(I)-YM))/XM
0013    3     IF(I-3)4,4,5
0014    4     H=XM*T1+YM
0015    5     Z(I-2)=H
0016    6     H=XM*T2+YM
0017          Z(NDIM-1)=H
0018          Z(NDIM)=XM*T3+YM
0019          IER=0
0020          RETURN
0021    7     IER=-1
0022          RETURN
0023          END
```

```
FORTRAN IV      V02.04          FRI 04-JAN-80 09:50:32         PAGE 001
CORE=31K, UIC=(212,1)                                         ,WILD/EX=WILD

0001          SUBROUTINE WILD
         C
         C    THROWS OUT WILD POINTS
         C
0002          COMMON/MISC/NRUN,TLD(10,2),IDIR(10,3),JOBTIT(60)
0003          BYTE TLD,IDIR
0004          COMMON/BINARY/NACT,NROS,MSHORT,MLONG,
            1     LCH(2),ICHN(3,10),TITLE(60,4),NRD(30),INCS(30),
            2     ITYPE(30),A(30),B(30),
            3     TIME(80,30),VALUE(80,30)
0005          BYTE TITLE
0006          CALL DISPLAY('SORRY, HAVEN''T GOT AROUND TO WRITING THIS YET!')
0007          RETURN
0008          END
```

# APPENDIX B

# RING TESTER

INTERNAL PRESSURE-ONLY COMPOSITE RING TEST FIXTURE

As part of Problem No. 112, an internal pressure-only tube test fixture was designed and built. The design of the fixture is esstentially the same as that of a fixture successfully used by the IIT Research Institute under contract to AFFDL. Technical Report AFFDL-TR-75-11, titled "Analytical-Experimental Correlation of the Biaxial State of Stress in Composite Laminates (T-300/5208)," may be used as a reference.

Several uninstrumented 0°/±45°/90° graphite epoxy rings have been successfully ruptured in the fixture. The results are disappointing, however, when specimens having high Poisson ratios, such as ±45° layups, are pressurized. In those tests, the large Poisson contraction in the axial direction allows extrusion of the internal rubber gasket between the specimen end and pressure collet. This destroys the pressure seal and prevents further application of fluid pressure.

A drawing of the fixture showing an assembly view of the main body, lock rings and pressure collets, is given in Figure B.1. A photograph showing the entire assembled fixture is given in Figure B.2. A schematic of the fixture is given in Figure B.3. The maximum pressure of this system is 5,000 psi. The gage accuracy is ±2% at full scale.

A pressure transducer must be installed in the pipe tee adjacent to the pressure gage. A Daytronic strain gage transducer, Model 502-3000G, has been used successfully with this fixture. If the data from the transducer is not required, a high pressure pipe plug (> 5,000 psi.) may be installed in its place.

To begin operation, fill the reservoir with hydraulic fluid. Open valves designated as Nos. 1, 2, 3 and 4 in Figure B.3. Fill the open reservoir at the end of the priming pump 3/4 full with hydraulic fluid. Close the relief valve at the other end of the priming pump. Pump the lever on the

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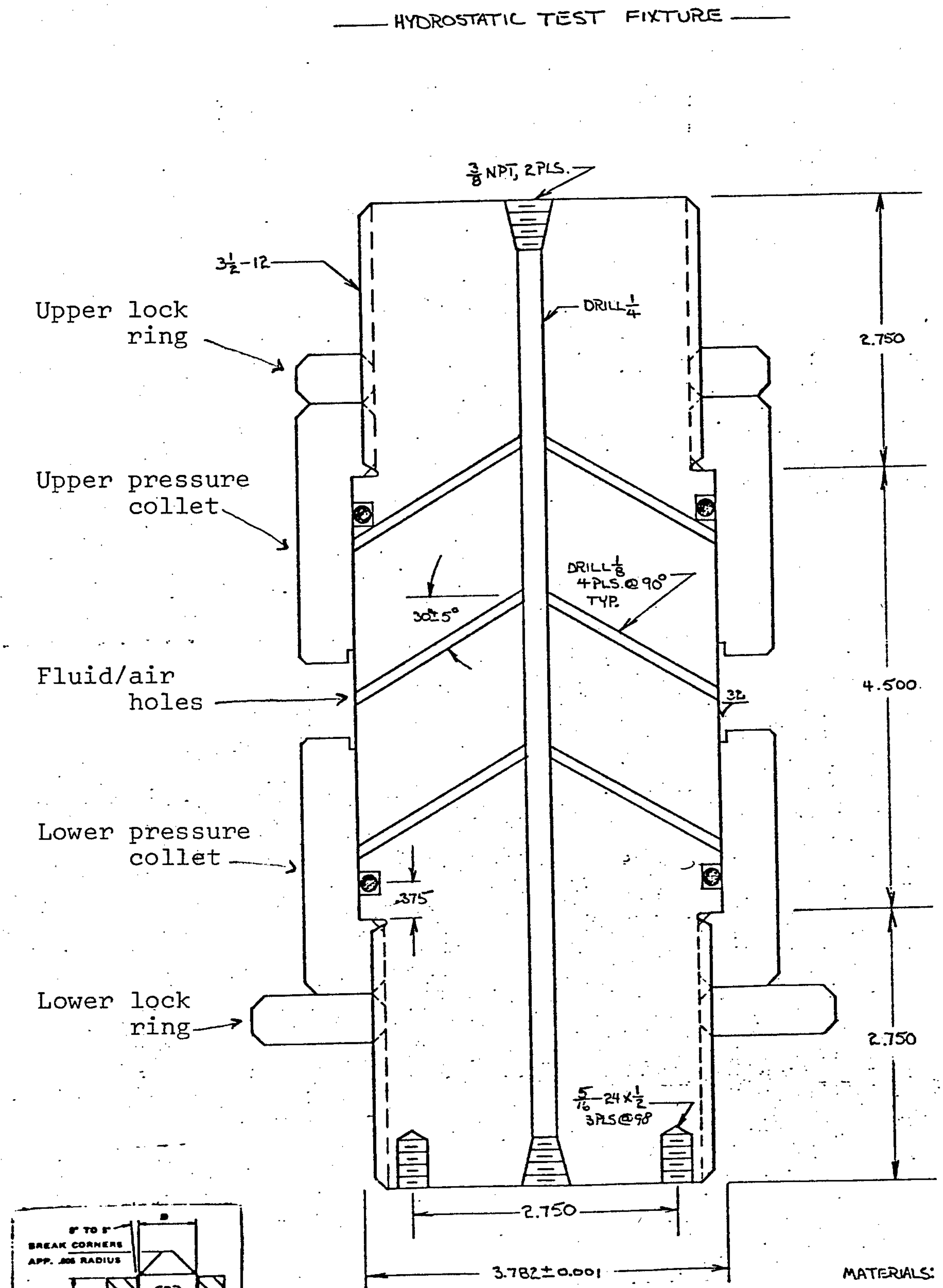


"O" RING GROOVE DETAIL

8° TO 5° BREAK CORNERS APP. .005 RADIUS

D = .280
C = .184
R = .005 MIN

SUPPLY & INSTALL 2 PC., 3/16 NOM. NEOPRENE "O" RINGS

Figure B.1 Dimensioned Drawing of Internal Pressure Only Fixture

MATERIALS: BODY – STEEL
LOCKNUTS – STEEL
COLLETS – 4340, $R_c$-45
SCALE – FULL
TOL. ± 0.005, EXCEPT AS NOTED
BREAK ALL CORNERS

N.L.H.
9-8-78

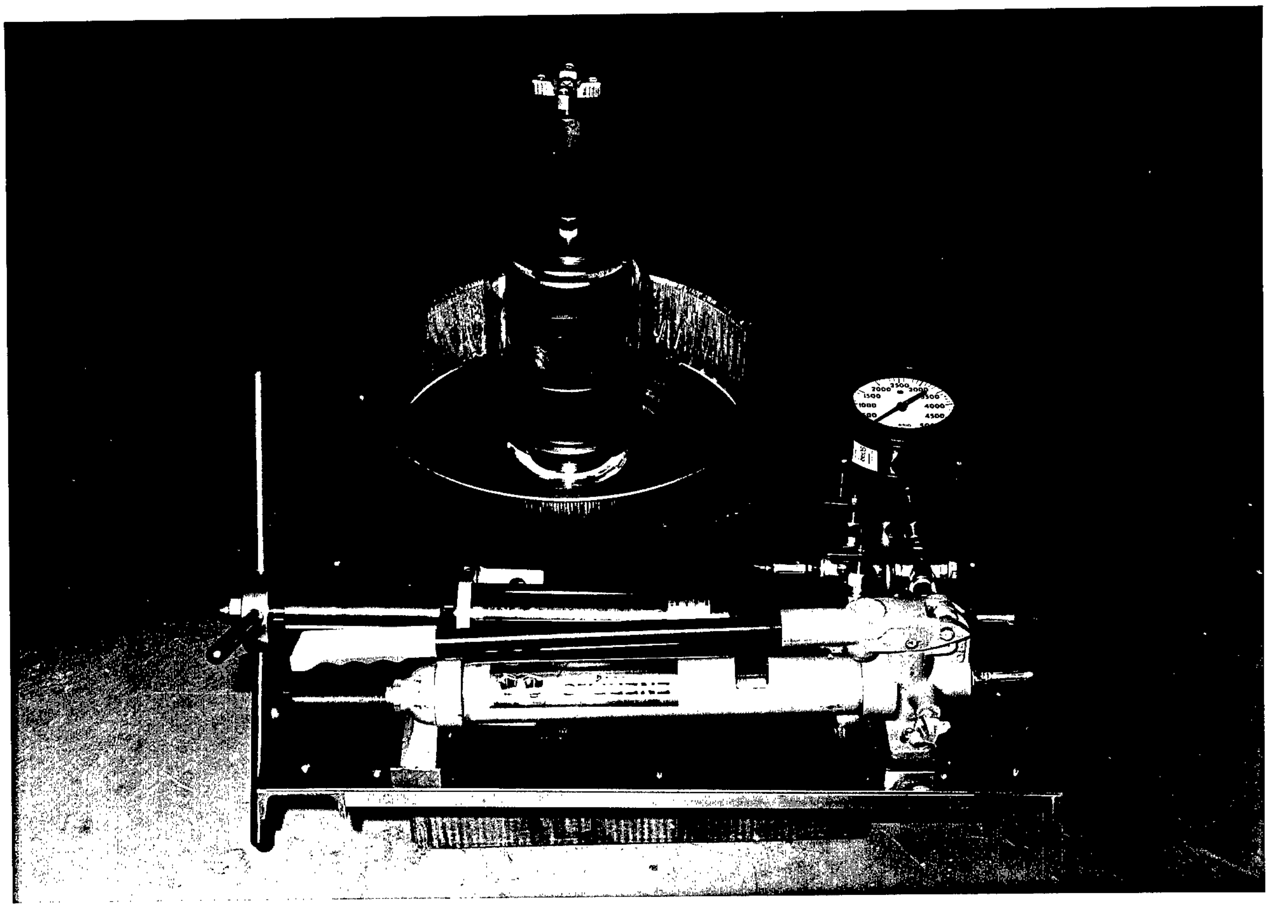

Figure B.2 Internal Pressure Only Test Fixture

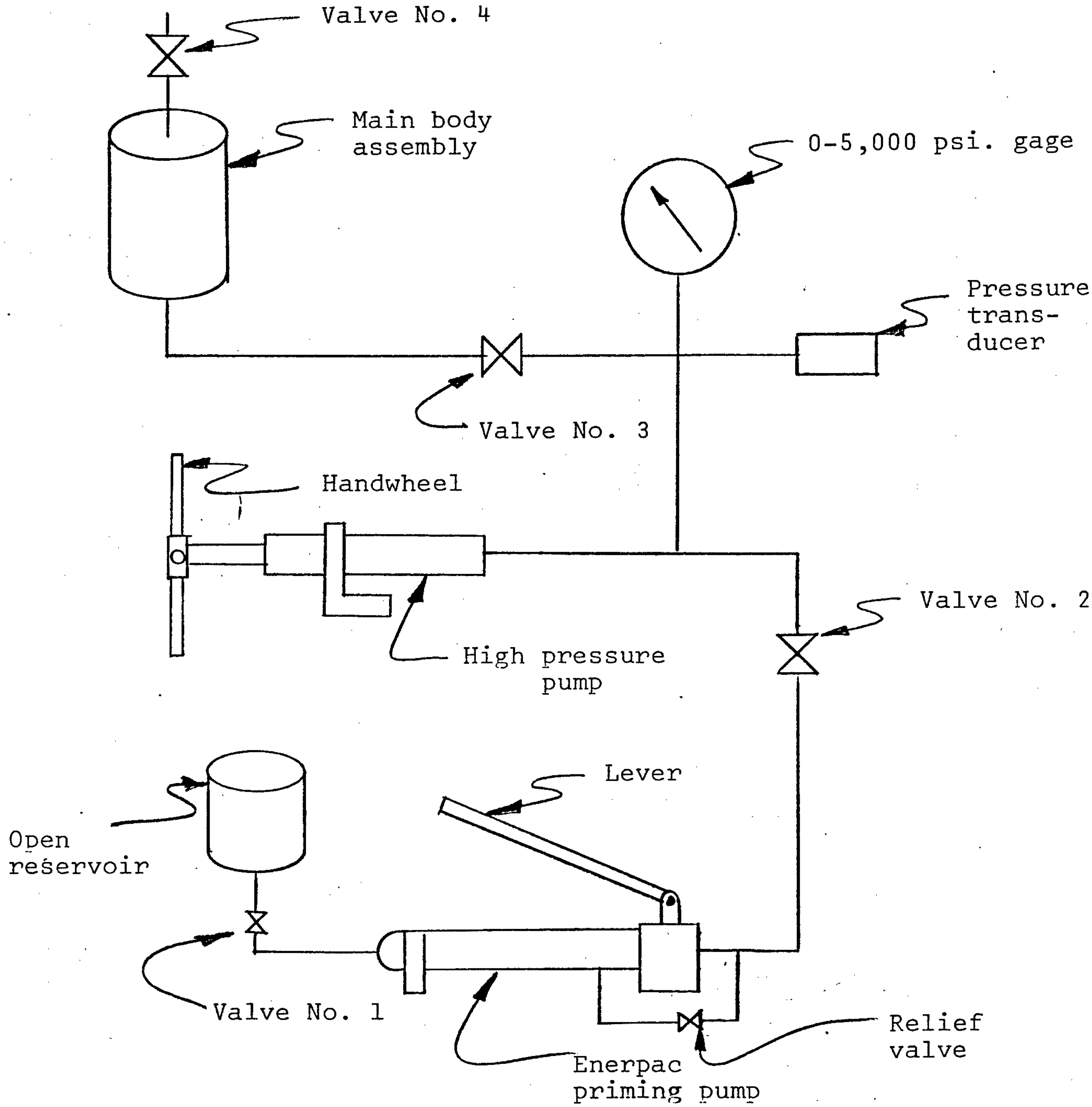


Figure B.3 Schematic of the Internal Pressure-only Composite Ring Test Fixture

priming pump until a steady flow of fluid leaks out of the main body, making sure that the open reservoir is never less than 1/4 full. Crank the handwheel on the high pressure pump clockwise until it stops. Close Valve No. 3. Slowly crank the handwheel counter-clockwise while pumping the lever on the priming pump. Keep a gage pressure of about 300 psi. Continue cranking until the shaft is fully extended. Open the relief valve on the priming pump to release the pressure.

To mount the test specimen, unscrew and remove the upper lock ring and upper pressure collet from the main body. Loosen the lower lock ring and screw the lower pressure collet down about 1.5 inches from its full up position. Cut a piece of the red rubber gasket tube about an inch longer than the specimen. This gasket tube is about 3 5/8" diameter and 0.10 inches thick, and was supplied by the Air Force. Slide the tube around the outside diameter of the main body, down far enough that it is centered around the fluid/air holes. Screw the lower pressure collet up the main body so that it slides over the gasket tube as far as it will go. Lock the lower lock ring. Slide the instrumented specimen over the outside of the gasket tube so that it rests on the lower pressure collet. Screw the upper pressure collet down so that the bottom edge rests on the specimen. The upper pressure collet should slide over the gasket tube just as the lower collet did. The length of the gasket tube may have to be trimmed so that the upper collet will rest on the specimen. Screw down the upper lock ring to lock the pressure collet. A photograph of the specimen in place is shown in Figure B.4.

Now that the specimen has been mounted, set up all of the signal conditioning for the pressure transducer and the specimen strain gages. Open Valves No. 1, No. 2, No. 3 and No. 4. Close the relief valve on the priming pump. As much air as

Figure B.4 Test Specimen Mounted in Fixture

possible must be gotten out of the system. This is done by pumping the priming pump until a steady flow of fluid comes out of Valve No. 4. The air that is trapped around the specimen will leave through the fluid/air holes in the main body.

After all the air is out, the pressure transducer can be calibrated against the pressure gage. Close Valves No. 2 and No. 3. By cranking the handwheel clockwise, a pressure will be produced at the pressure gage and transducer without applying pressure to the specimen. To release the pressure, crank the handwheel counter-clockwise until the shaft is fully extended, and open Valve No. 2 and the relief valve on the priming pump.

To test the specimen, close Valves No. 2 and No. 4. Open Valve No. 3. Place the plexiglass tube over the specimen so that it rests on the lower lock ring. Apply pressure to the specimen by cranking the handwheel clockwise. To release the pressure, open Valve No. 2 and the relief valve on the priming pump. After the specimen has ruptured, drain the fluid out of the drain pan by removing the pipe plug in the bottom of the pan.